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A. G. KANDOIAN

2,368,663

BROAD BAND ANTENNA

Filed May 15, 1943

Fig. 1.

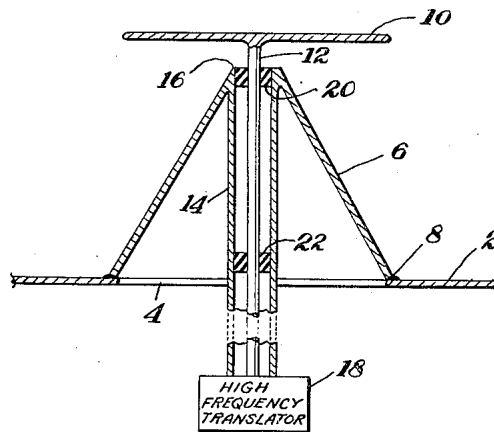


Fig. 2.

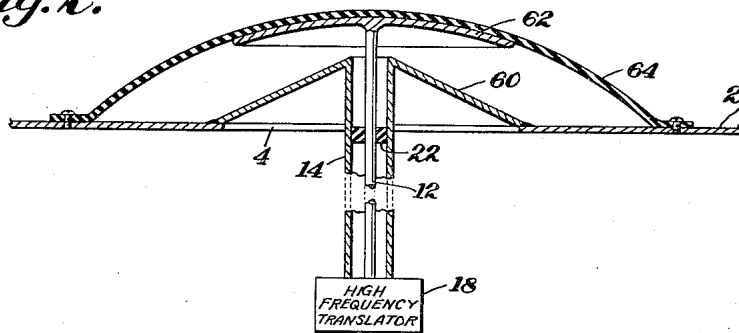


Fig. 4.

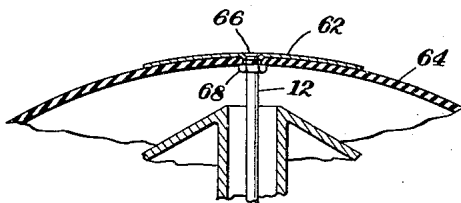
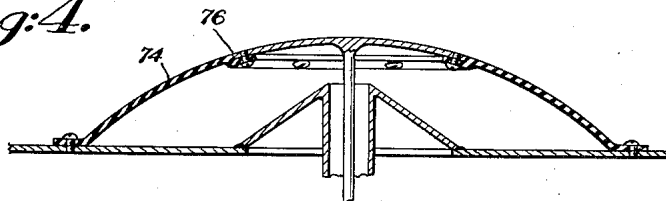


Fig. 5.

INVENTOR.

ARMIG G. KANDOIAN

BY

Percy P. Lantz
ATTORNEY

UNITED STATES PATENT OFFICE

2,368,663

BROAD BAND ANTENNA

Armig G. Kandoian, New York, N. Y., assignor to
Federal Telephone and Radio Corporation,
Newark, N. J., a corporation of Delaware

Application May 15, 1943, Serial No. 487,075

8 Claims. (Cl. 250—33)

This invention relates to radio antennas and in particular to broad band antennas for operation at ultra-high frequencies.

In keeping with progress made during the last few years in the development of ultra-high frequency radio technique, and applications thereof to aircraft communication, direction finding, and so forth, it has become necessary to develop special antennas and antenna systems suitable for installation on such aircraft. Flying conditions are such that these antennas must necessarily be small and rigid in their construction and also offer a minimum of wind resistance, in order that the flying efficiency of the aircraft will be unimpaired. In accordance with my invention I have provided a small rigid antenna suitable for mounting on the surface of the fuselage or other component of the airplane structure and in certain embodiments I have also provided a streamlined protecting shield or housing covering or so cooperating with the construction of the antenna system as to greatly reduce wind resistance. This housing preferably takes the form of a "blister" which is only slightly elevated from the normal surface of the aircraft on which it may be installed.

It is therefore an object of my invention to provide an antenna structure of great rigidity.

Another object of my invention is to provide an antenna structure suitable for mounting on aircraft in a manner such that it will produce a very low wind resistance.

Another object of my invention is to provide an antenna structure suitable for operation over a wide frequency band.

These and other objects of the invention will be best understood and appreciated from the following description of different embodiments thereof, described for purposes of illustration and shown in the accompanying drawing in which:

Fig. 1 is a cross-sectional view of an antenna structure according to one embodiment of my invention;

Fig. 2 is a cross-sectional view of an antenna structure in accordance with a second embodiment of my invention.

Fig. 3 is a modification of the antenna structure shown in Fig. 2; and

Fig. 4 is a further modification of the antenna structure shown in Fig. 2.

Several forms of broad band antennas for operation at ultra-high frequencies are known in the prior art. In general, a characteristic feature of a broad band antenna lies in the fact that the antenna impedance is substantially constant

over a wide frequency band. One way of obtaining this substantially constant impedance is to so devise the antenna structure that the energy flowing in the antenna encounters no abrupt change of impedance as it passes along the antenna and is radiated into space. One known form of broad band antenna having the above described characteristics consists of two conical surfaces of revolution positioned so as to have a common axis and having their apexes adjacent each other. This form of antenna is difficult to construct unless bracing members are employed to support the bases of the cones forming the antenna. These structural supports are usually positioned in the field of the radiated energy and unless formed of low-loss insulating material tend to absorb energy. Furthermore, if a structure of this type were employed as an aircraft antenna for example, it would introduce such great wind resistance as to be impractical.

In accordance with my invention, I retain one of the conical elements of an antenna such as above described but for the other conical element I substitute a disk which may be either flat or slightly concave. The disk may be either round, square, or of other configuration, but because of symmetry the round form is preferred.

Referring now to Fig. 1, I have illustrated an antenna structure which would be suitable for use on an airplane. For example, the reference character 2 may represent a portion of the surface of a fuselage. In general, however, and without reference to where the antenna may be mounted, this surface may be formed of either a conducting or insulating material depending upon the band of frequencies for which the antenna is to be employed, as will be described presently.

The surface 2 may extend over a considerable area and although preferably substantially flat, it need not be necessarily so. Over a hole 4 in the surface 2 is mounted a conical antenna element 6. If the surface 2 is of metal, the element 6 may be welded thereto at the point 8. Other forms of mounting could obviously be employed. If the surface 2 is of insulating material, many forms of mounting could be devised by those skilled in this art but since the manner of mounting forms no part of my invention, no details or description thereof are given.

The antenna element 10 consists of a round disk mounted on the end of a rod 12, for example, by welding. The rod 12 forms the inner conductor of a concentric conductor transmission line, the outer conductor 14 of which, is connected to the apex 16 of the conical element 6.

The transmission line extends to a distant point where it may be connected to either a transmitter or to a receiver or both, shown in Fig. 1 as a high frequency translator 18. Insulating members 20 and 22 space the transmission line conductors and also rigidly support the inner conductor 12, which in turn, rigidly supports the disk 10. The impedance of the transmission line is such that it matches the impedance of the antenna system comprising the elements 10 and 6. If the antenna is employed for transmitting purposes, the high frequency waves, upon reaching the end of the transmission line, diverge and travel toward the outer extremities of the antenna elements from which point they spread into space in the form of radiation as is well understood in the art.

Referring to Fig. 2 I have illustrated another embodiment of my invention similar in most respects to the embodiment shown in Fig. 1, but wherein the antenna structure is completely shielded so as to reduce wind resistance to a minimum. The cone shaped antenna element 60 has a larger base in proportion to its height, than the element 6 shown in Fig. 1 for the purpose of reducing the overall height of the antenna. The manner in which the cone is attached to the surface 2 may be similar to that described above as in connection with Fig. 1.

The antenna element 62 is somewhat mushroom-shaped so as to conform to the inner surface of a concavo-convex shield 64 which is of non-conducting material. The purpose of the shield is to reduce wind resistance to a minimum. The antenna element 62 may be in the form of a metal disk or it may be sputtered or otherwise deposited on the inner or outer surface of the shield 64.

Fig. 3 illustrates a modification of the structure shown in Fig. 2 wherein the metal disk 62 is fastened to the outside surface of the shield 64. In this case it is necessary for the conductor 12 to pass through the shield where it may be fastened to the disk in some suitable manner such as shown in Fig. 3 as a clamping arrangement consisting of a head 66 and a nut 68. Should the disk 62 be formed by sputtering metal on the shield, the clamping arrangement could be as shown in Fig. 3, or the head 66 could be made flush with the outer surface of the shield and the metal of the disk sputtered thereon. It is preferable that the element 62 be on the concave side of the shield rather than on the outer or convex side since the shield thereby offers a mechanical protection to the antenna element.

As above stated the surface 2 may be of either metal or insulating material. If of metal, the surface acts as an extension of the cone shaped antenna element and electrically it has the effect of lowering the band of frequencies over which an antenna of a given size and shape would operate. In other words when constructing an antenna in accordance with my invention, the effect of the surface 2 must be considered. If the surface is normally of insulating material and it is desired that an antenna structure be provided having a band width lower than it would normally be with an insulating surface, an artificial conducting surface placed over the insulating surface, could be provided. The extent to which this surface extends beyond the base of the cone determines in some degree the position of the frequency band. The greater the extension, the lower the band frequencies.

In Fig. 4 I have illustrated a modification of

the manner in which the disk-shaped antenna element may be fastened to or mounted on the non-conducting shield. In this figure the shield 74 does not extend completely over the disk-shaped antenna element, but joins the periphery of the disk at 76 where it may be attached thereto by screws, threads, rivets or other fastening means.

While I have described above the principles of my invention in connection with specific apparatus and particular modifications thereof, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of my invention as set forth in the objects of my invention and the accompanying claims.

I claim:

1. A broad band antenna comprising means defining an extended conducting surface, a substantially conical antenna element supported on said surface and conductively connected thereto, said surface extending substantially perpendicular to the axis of said conical element, a disk-shaped antenna element, said disk-shaped element being positioned adjacent the apex of said conical element, and a coaxial transmission line passing through said surface defining means and said conical element, the inner conductor of said line being arranged to support said disk-shaped element and the outer conductor of the line being connected to the apex of said conical element.

2. A broad band antenna in accordance with claim 1 and further comprising a non-conducting shield extending between said disk-shaped element and said surface.

3. A broad band antenna in accordance with claim 1 and further comprising a streamlined non-conducting shield extending between said disk-shaped element and said surface, and means for supporting said disk-shaped element from said shield.

4. A broad band antenna comprising means defining an extended conducting surface, a substantially conical antenna element supported on said surface and conductively connected thereto, a non-conducting streamlined shield mounted on said surface and extending over said conical element, a disk-shaped element mounted on said shield, said disk-shaped element being positioned adjacent the apex of said conical member, and a transmission line comprising an inner and an outer conductor passing through said surface and said conical element, said inner conductor being connected to said disk-shaped element and said outer conductor being connected to said conical element at said apex.

5. A broad band antenna in accordance with claim 4 wherein said disk-shaped element comprises a metal deposit on a surface of said shield.

6. An antenna construction comprising a pair of cooperating antenna elements, and a wind shield housing the antenna elements at least in part to present therewith an outer substantially convex surface, one of the antenna elements being disk-shaped with one side thereof being convex, and said shield being concave-convex with the concave side thereof arranged adjacent the convex surface of said disk-shaped element.

7. An antenna construction comprising a pair of cooperating antenna elements, and a wind shield housing the antenna elements at least in part to present therewith an outer substantially convex surface, one of the antenna elements being disk-shaped and the shield being annular,

and means connecting the inner edge of said shield to the edge of said disk-shaped element.

8. An antenna construction for use on aircraft and other devices where it is desirable to maintain wind resistance at a minimum comprising a conical antenna element to be disposed with the base thereof on the outer surface of the aircraft, a disk-shaped antenna element positioned adjacent the apex of the conical element, and

a concavo-convex wind shield housing the antenna elements at least in part and forming with the surface of the aircraft the appearance of a "blister", said disk-shaped antenna element having one side thereof convex, with the concave side of the shield arranged adjacent thereto.

ARMIG G. KANDOIAN.

Fig. 1. W6UYH inspects a vertically polarized temporary test installation of the 40 to 500-mc discone.

JOSEPH M. BOYER, W6UYH, ex-W8PVL*

A single efficient antenna for operation on any frequency from 40 to 500 mc that requires no tuning stubs or matching transformers, has an s.w.r. under 2:1 and provides gain over a dipole throughout its spectrum.



Discone—40 to 500 Mc Skywire!

ONE ANTENNA CAPABLE of highly efficient performance from six to three-quarter meters—period! No tuning stubs or matching transformers needed. Voltage standing wave ratio in the transmission line under 2:1 over the entire stretch of r.f. territory quoted. Once up you can forget it, come gale or high water. That, ham brethren, is the discone.

The writer decided upon the discone for v.h.f. work when the XYL made it clear she didn't want the brand new QTH looking like a radar development laboratory. Now visiting hams say, "Yeah, that's a nice ultra-modernistic weathervane up there but where's the skywire?" A few minutes of listening on 2 meters, however, with the OM using a coaxial switch to cut from a well matched ground plane antenna to the "weather vane" and they climb up on the roof for a closer look.

While not too familiar to the ham fraternity,¹ the discone was developed and used during World War II. Some designs now in the patent files of this and other countries show some similarity in theory of operation and appearance to the discone, but the exact configuration of top disk and cone is the brain child of Armig G. Kandonian.²

The discone consists of a metal cone which is a continuation of the shield of a coaxial cable, and a top disk which is connected to the inner conductor of the same coaxial line. The slant height of the

cone (shown in Fig. 2 as dimension d) is equal to an electrical quarter wavelength at the lowest frequency for which operation is desired. The flare angle at the apex of the cone has a first order effect upon the input impedance of the discone antenna. The exact diameter of the top disk is only critical if the discone is to be operated over the first few megacycles of its low frequency design point; otherwise its effect upon input impedance is secondary.

Physical dimensions are given in Fig. 2 for the three models of the discone to be described. Model A is designed to cover the frequency range 40–500 mc; model B, 400–1,200 mc; and model C (800–5,000 mc) is a scale replica of the 40–500 mc version whose purpose was to provide a means of measuring the radiation pattern of the discone using the model antenna range technique. This technique will be described later in the article.

Theory of Operation

While a rigorous analysis of the discone would result in an unwieldy mass of boundary equations, a brief non-mathematical description should be of value particularly to those desiring to modify the basic design for their own special needs.

There are several non-mathematical analogies which permit a visualization of the operation of the discone, but two are particularly valuable. First, the discone antenna may be looked upon as a "hi-pass" filter network. Imagine such a network hooked between two transmission lines, one labeled "Communications Network" and the other "Space Network." If we add an energy source in the form

*Design Engineer, Douglas Aircraft Co., 208 Calle de Madrid, Hollywood Riviera, Redondo Beach, Calif.

¹ Lester, "Looking Over V-H-F Antennas," *CQ*, November, 1948.

² Federal Radio and Telegraph Company.

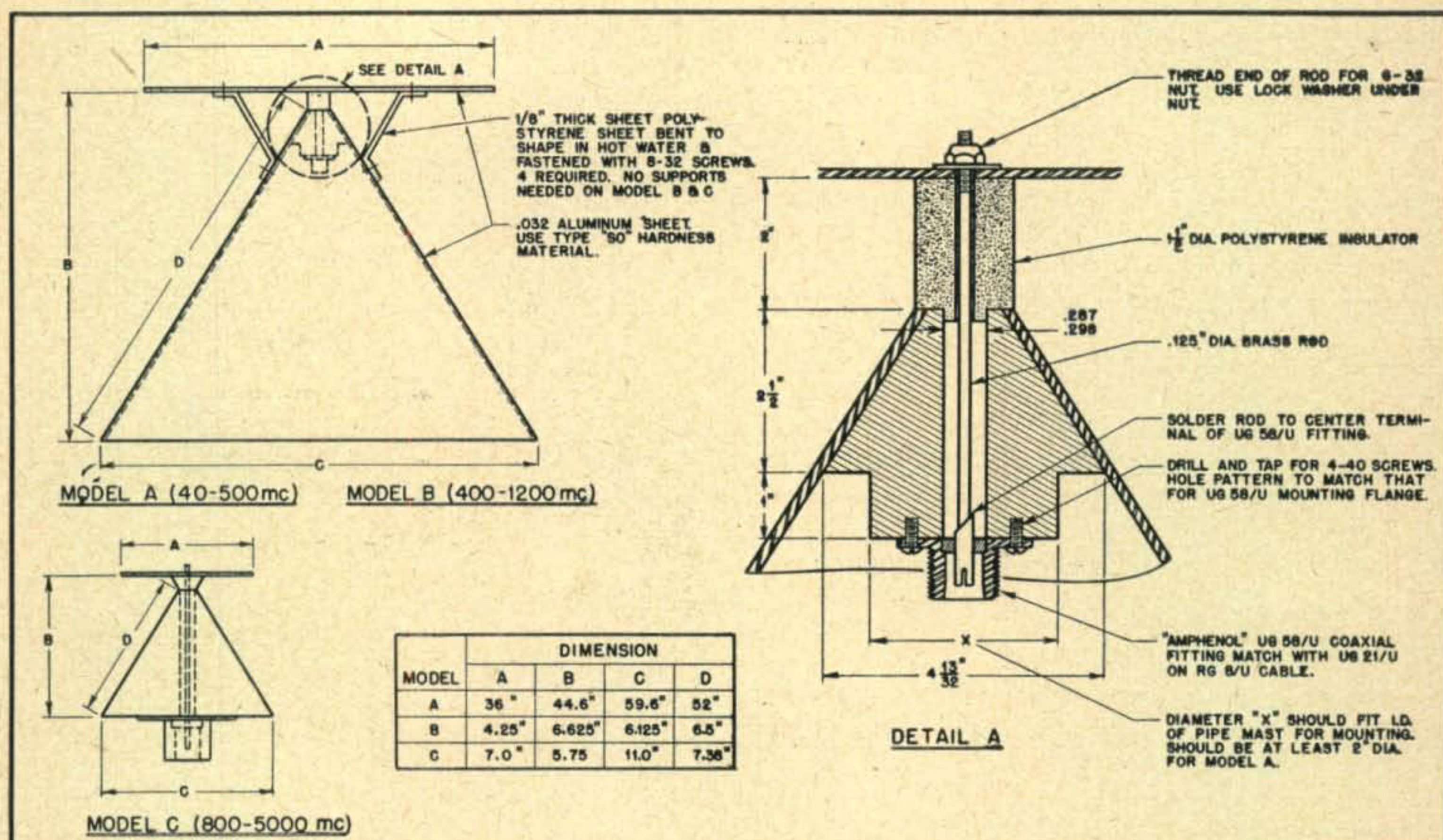


Fig. 2. Constructional details and dimensions of discone models A, B, and C. Each of the three antennas shown, spanning the frequency band 40 to 7,500 mc, will offer almost constant input impedance to a coax feed line.

of a very high frequency signal generator to the "Communications Network" it will be found that for all frequencies below some critical value the filter will pass little energy from the generator to the "Space Network." High magnitude voltage standing waves will exist on the line connecting the generator to the filter.

However, once the critical frequency is exceeded the voltage standing wave magnitude will quickly drop to a very low value and energy will pass smoothly from the "Communications Network" to the "Space Network." We might call such a "hi-pass" filter a "broad band" network. From theory such a network, after the critical low frequency limit is passed, will offer little attenuation to all frequencies on up to light waves. Practical networks fail to achieve this performance either because lumped elements such as coils begin acting like condensers after a certain frequency range is covered; or if distributed elements such as transmission line sections are used in its construction a frequency region is reached where minute defects in fabrication and surface pits and "bumps" present discontinuities—that is, begin to act like lumped elements and the network design fails.

The discone, then, may be visualized as a "hi-pass" network with the above limitations. The familiar dipole, on the other hand, acts like a "band-pass" network. Over only a very narrow band of frequencies does it pass energy from the "Communications Network" to the "Space Network." The objection may be raised that a dipole will radiate first as a half-wave antenna, then as a full wave, and so on. Its input impedance, however, at each of these resonance points changes radically and

consequently, unless the generator's impedance is matched to the antenna impedance at each of these points, high standing waves will still exist with poor energy transfer. This change of input impedance with frequency, relatively speaking, does not occur with such an antenna as the discone.

Intrinsic Impedance

The question then arises: what sort of radiation characteristics does an antenna have to possess in order to function like a "hi-pass filter network"? The first step in this direction is to define the term *intrinsic* or *wave impedance*. There is nothing formidable about this term, and as ham radio moves into the region beyond 2,000 megacycles on a large scale its use in the hobby's jargon will become common. Today most amateurs are familiar with the picture of radio energy being merely *guided between* the conductors or boundaries of a transmission line. (The earth, for example, serves as a rather leaky waveguide wall or boundary for vertically polarized "ground" waves on most ham frequencies.)

The *intrinsic* or *wave impedance* is simply the ratio of the electric to magnetic fields existing between a particular pair or set of such wave boundaries. It is the wave equivalent of the familiar law of Ohm, $R = E/I$. This concept permits assigning a value of impedance to the empty space existing between all the transmitting and receiving skywires in the universe. The assigned value is 377 ohms and space is then looked upon as a mammoth transmission line with this value of intrinsic impedance.

The job of any antenna is to act as an impedance matching transformer between the impedance of the communications networks connected to them

and the above mentioned space transmission line. The sharply tuned transformer represented by the dipole is one way of doing this job, but its characteristics are not suited for operation over a wide band of frequencies.

The discone goes about its space matching duties in a slightly different manner. Assume a very high frequency signal generator connected to a long coaxial line of convenient characteristic impedance, say 52 ohms. At a frequency of 300 mc, for example, energy passing down the line and reaching the open end reflects back and sets up high magnitude voltage standing waves. Little power can leak out of the open end and propagate into space. If, however, over a distance of 10 feet or more the spacing between the inner conductor and the shield of the coaxial line is gradually increased so that at the open end the shield is now a tube several feet in diameter—then it will be found that almost all energy supplied to the line is being radiated. The standing waves along the line will, for practical purposes, have vanished. Radiation will continue to occur even when the signal generator is tuned to higher and much higher frequencies. What we have done is build a wide band antenna known as a form of annular slot, which in its way is a brother to the discone.

To see the similarity attention is directed not to the open end of the line but to the gradually tapering section between the signal generator and the slot radiator at the open end. This section is known as a *taper transformer*. Such a configuration of

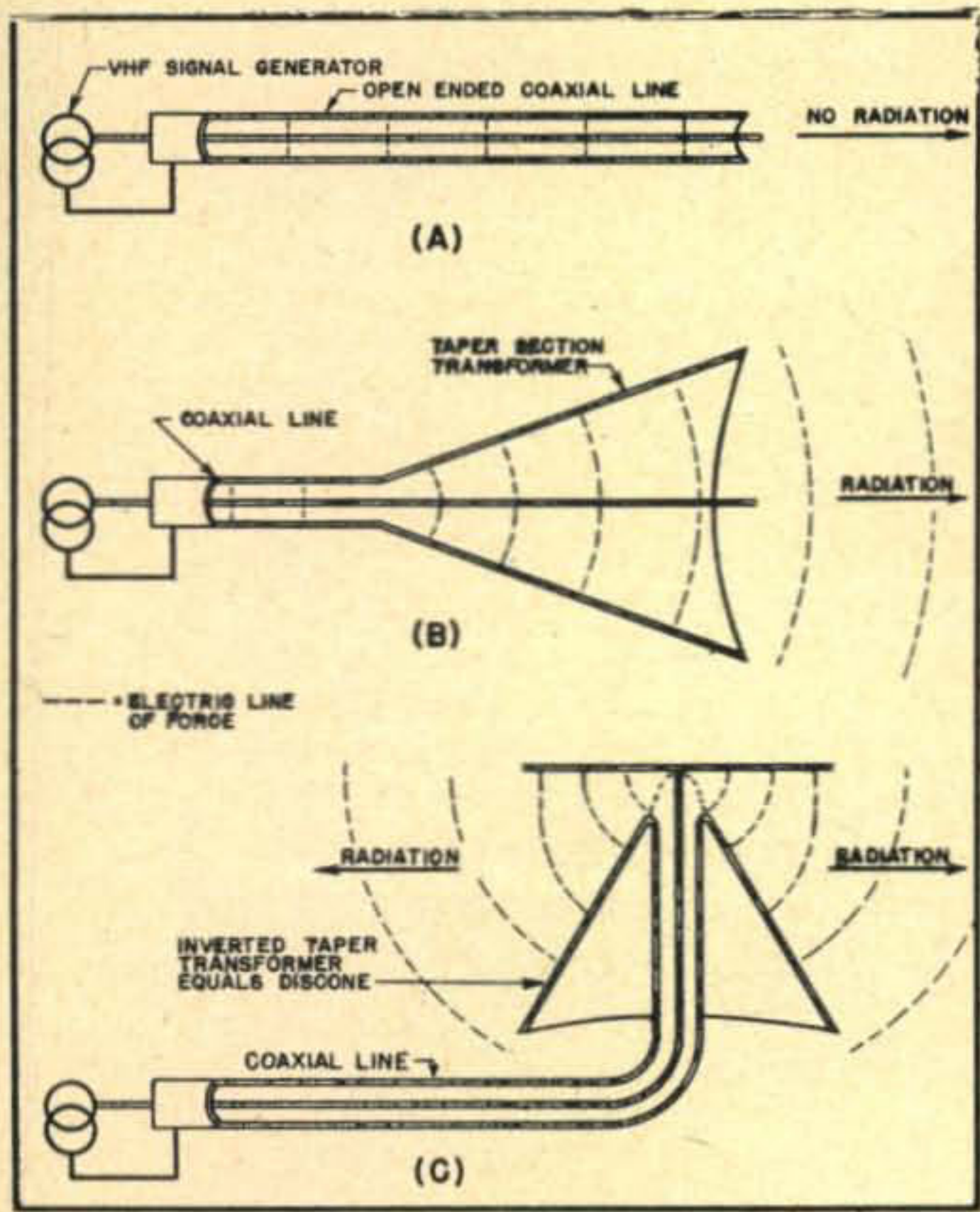


Fig. 3. Evolution of the discone antenna from an open-ended coaxial line. The relationship shown is true only when the discone is operating at least a half octave above its low frequency cutoff point.



Fig. 5. The model B discone, shown mounted on the metal roof of the test car, proved to be very efficient in tests over a 12-mile path on the amateur 420-mc band. Transmitter used had a power output of $2\frac{1}{2}$ watts.

boundaries starts out with a low value of wave impedance because of the electrical dimensions between the shield and inner conductor. As these spread apart the wave impedance changes gradually until somewhere along its length it “looks” like the value for space. The location of this point will change with a change in frequency, either moving further back down the throat of the taper transformer or out toward the open end. But in either case from this point forward in the taper transformer the radiated waves will find themselves in an environment which has the electrical “feel” of space and from there on out into actual space electromagnetic waves will propagate with little loss.

Tapering boundary transformers are the theory basis for many types of microwave radiators such as the electromagnetic sectorial horn used in radio city-to-city links, and they also explain the operation of the discone.

Coaxial Taper Transformer

All the foregoing ground had to be covered in order that we might finally see that the discone is a *coaxial taper transformer* in which the shield of the transmission line has been folded back on itself at the beginning of the taper and flared out into a cone (Fig. 3). The top disk is provided for two good reasons. One, it provides a continuous boundary, symmetrical in all directions from the center of the system, upon which the electric field lines of force extend themselves as they advance out along the cone into space. Two, at the low frequency limit point (where the electrical diameter of the open end of the taper is barely sufficient in size to support radiation) the top disk acts as a capacitive plate to permit the discone to function quite like a top loaded dipole. This low limit point occurs at a frequency for which the slant height of the cone is equal to an electrical quarter wave.

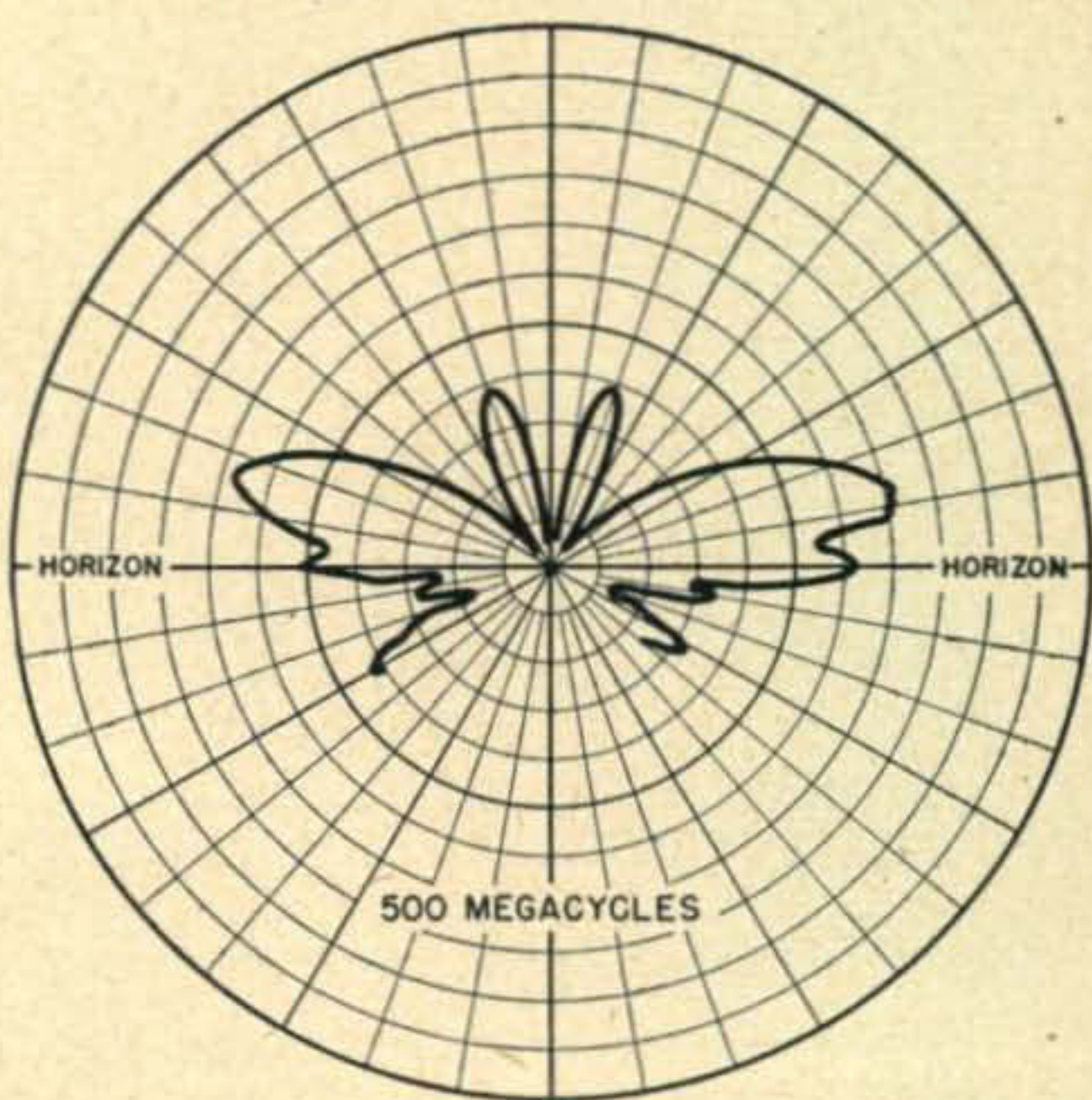
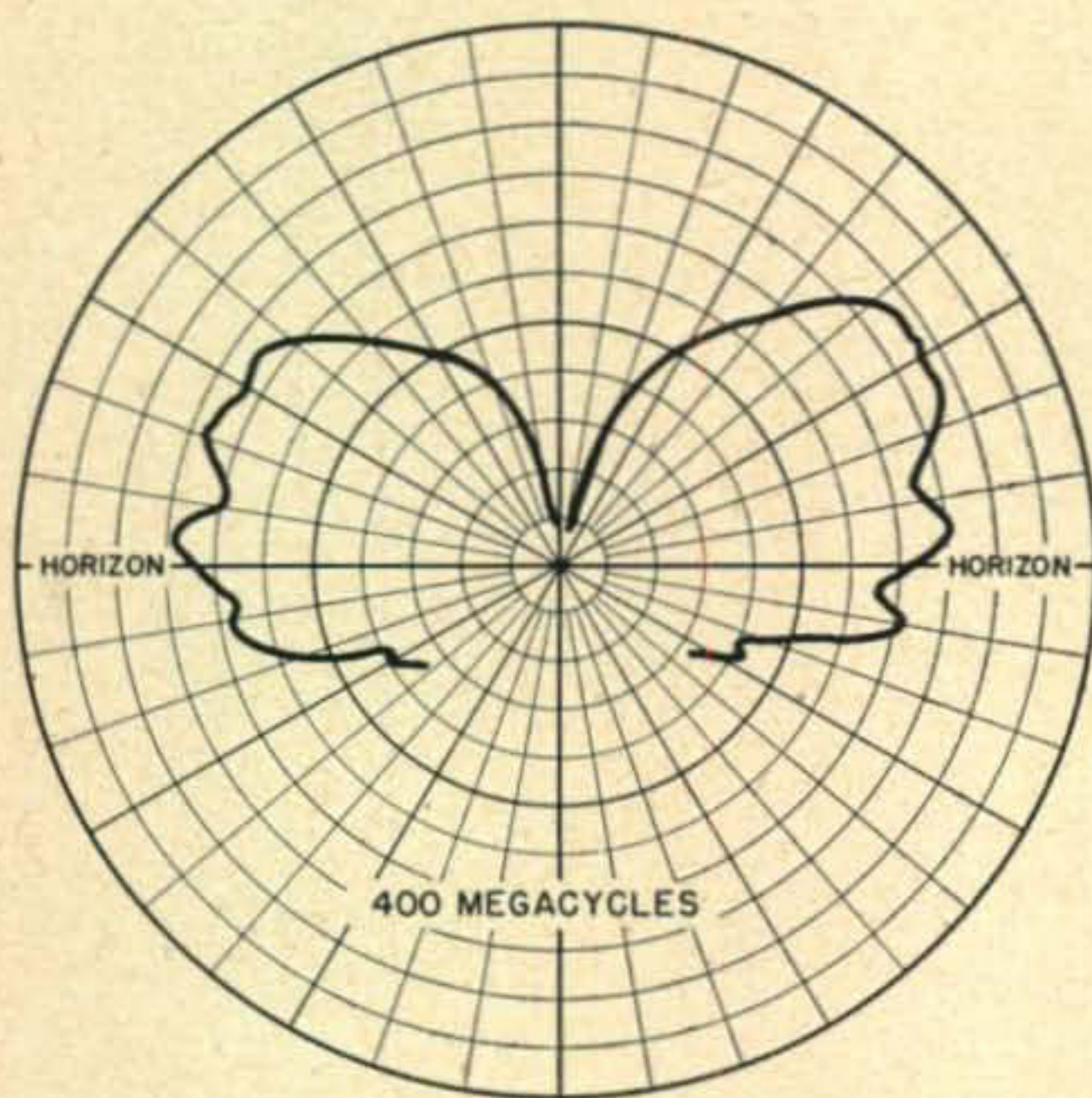
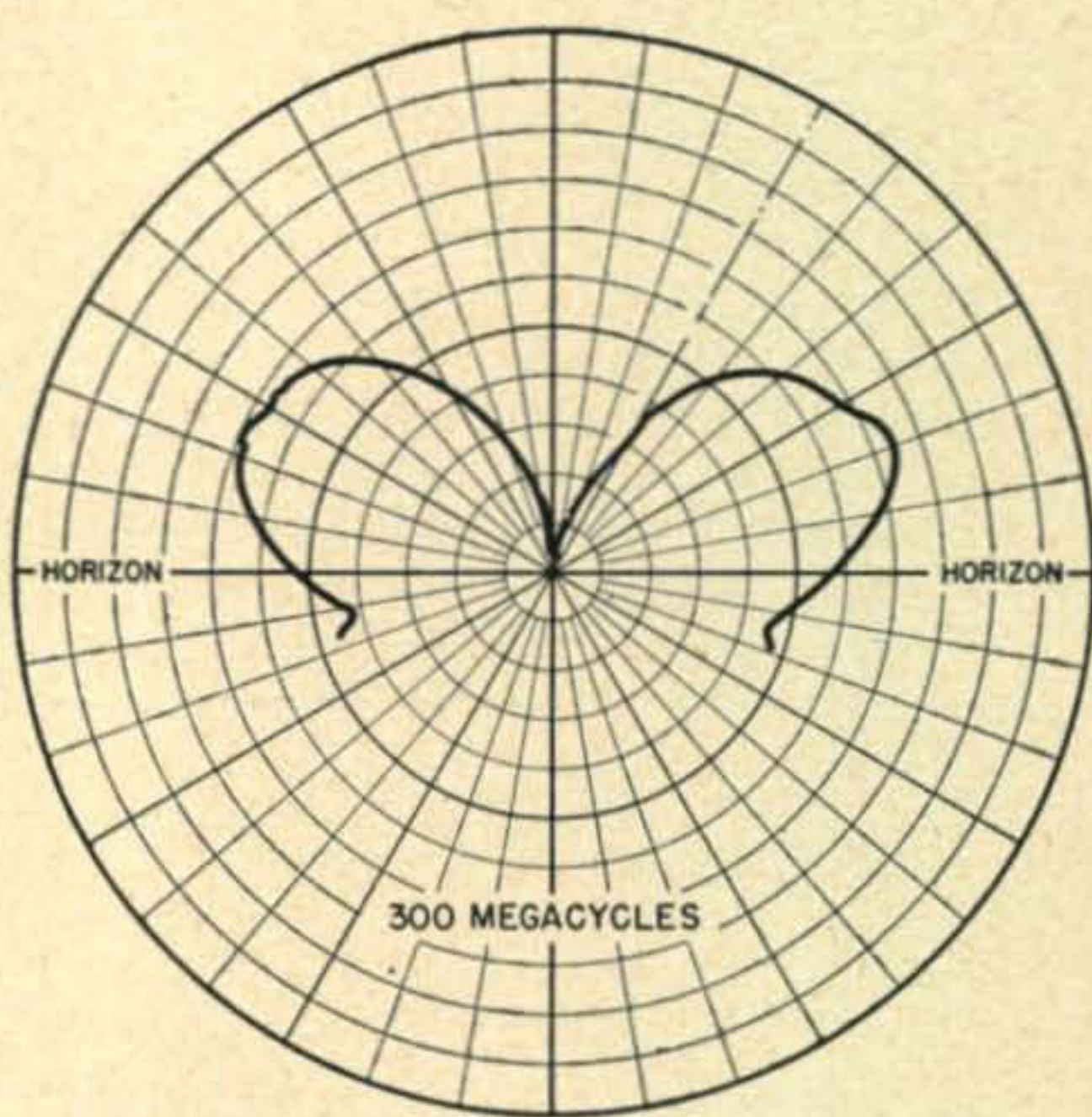
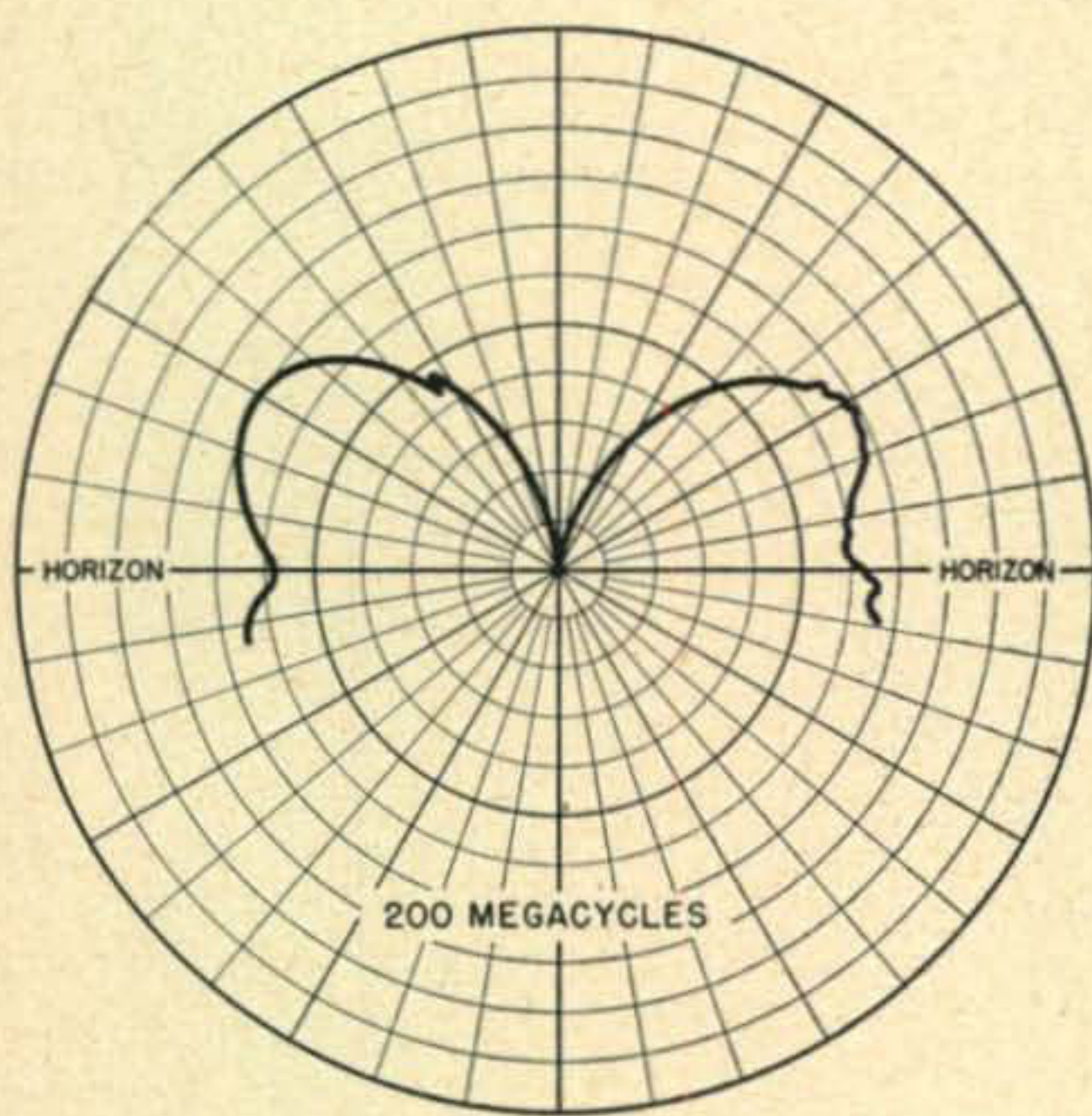
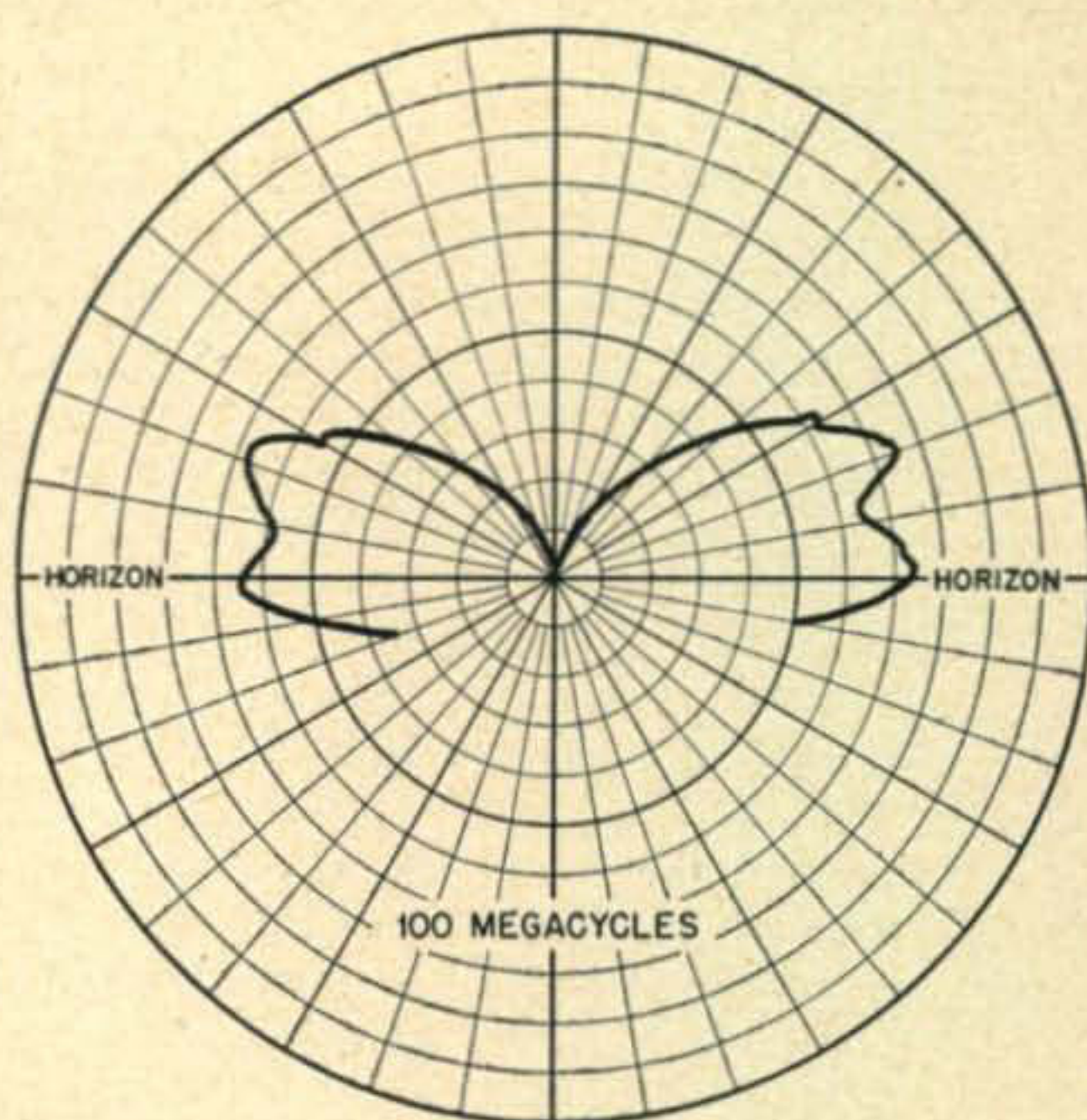
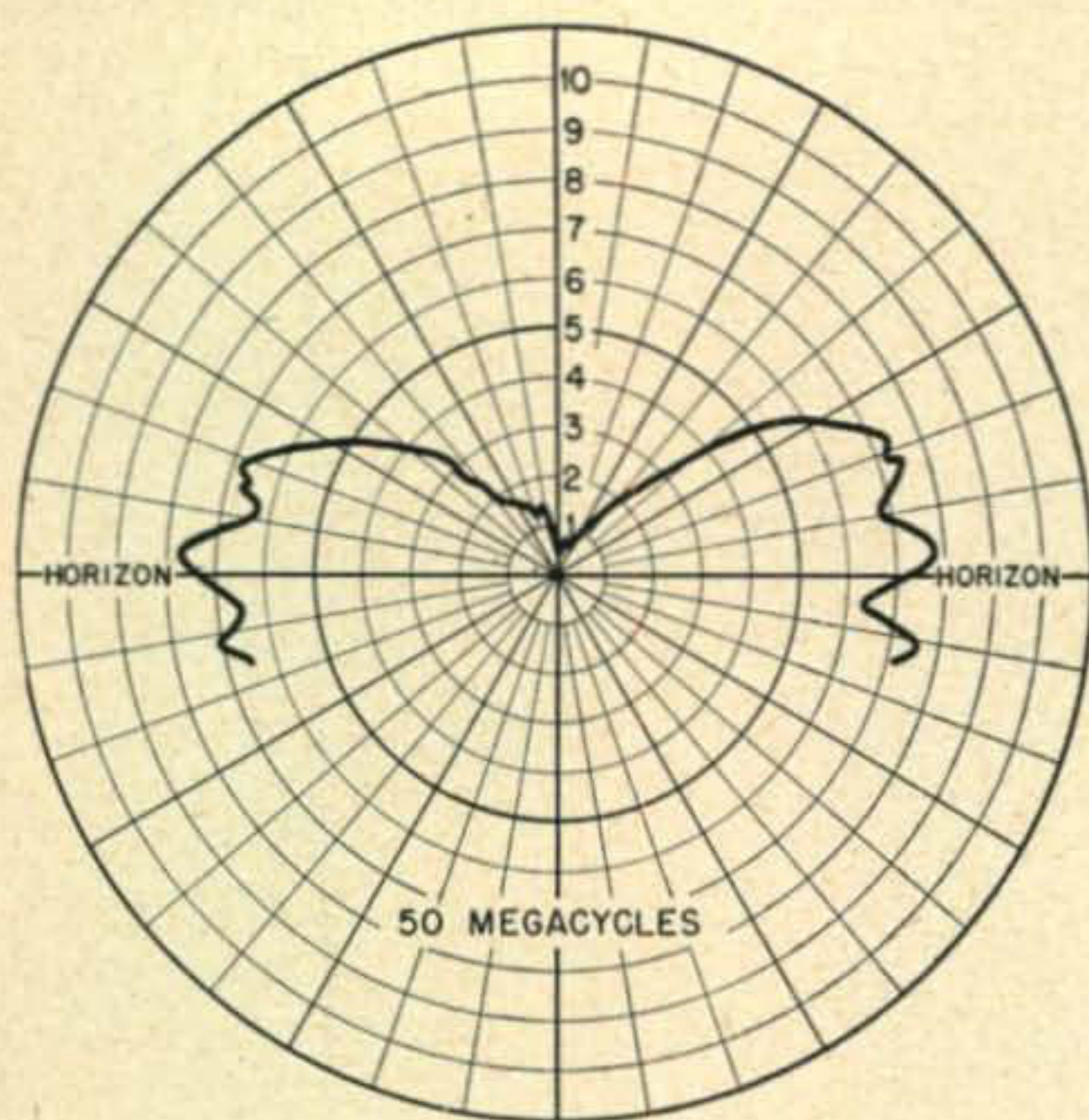


Fig. 4. Asymmetry of scale model C radiation patterns is caused by reaction of objects within the antenna fields.

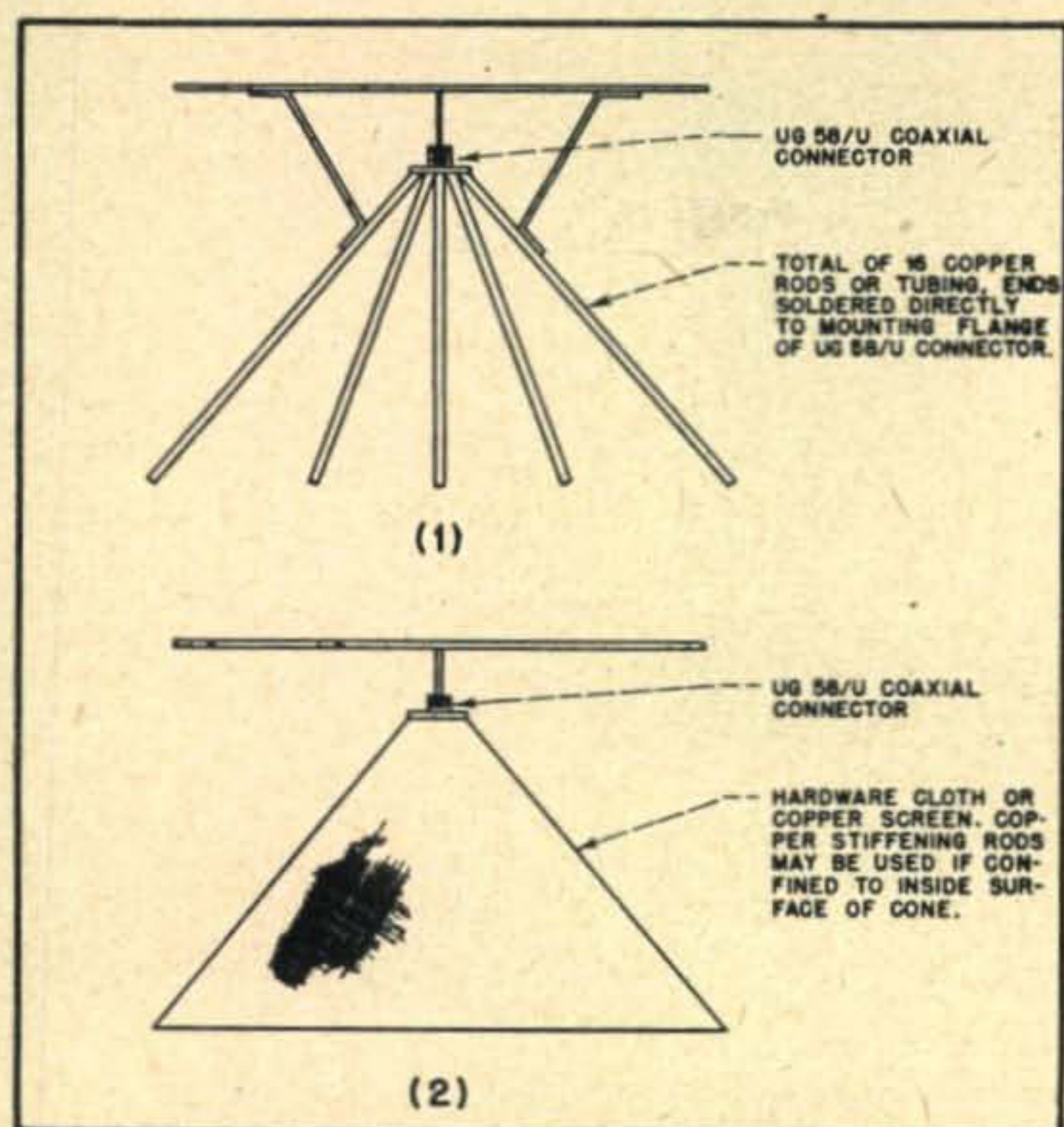


Fig. 6. Two alternate methods of constructing simple discone antennas.

Radiation Patterns

As mentioned previously, the radiation patterns of the discone were secured by the model antenna range technique.³ A one-twentieth scale model of the discone was constructed to operate over a frequency range of 800 to 5000 mc. An Army surplus APT-5 transmitter unit was used from 800 to 1,500 mc to excite a large pyramidal horn radiator used to "illuminate" the model antenna under test. From 1,500 mc up a Klystron transmitter was available.

The model discone was mounted upon a specially constructed dielectric tower. This tower, in turn, was fixed upon a motor driven circular table which permitted the model antenna to slowly rotate about its central axis either in the vertical or horizontal planes. As the model turned at approximately 1 r.p.m. it was "illuminated" by the uniform wave front beam of the horn radiator mounted upon the laboratory building. All signals to the model were square-wave modulated to avoid danger of frequency modulating the Klystron.

A bolometer detector (10 ma Littelfuse in a special holder) connected to the model discone demodulated the received signal, passing the audio component back to tuned amplifiers in the laboratory. To record this signal graphically in the form of a polar plot of field strength a specially designed cathode ray oscilloscope with servo-driven deflection coils was provided. The oscilloscope screen is photographed during the process of rotating the antenna through 180 or 360 degrees to secure a permanent record. The plots shown in Fig. 4 were projected and traced from such films.

As can be seen, the vertical pattern changes relatively little over the large span of frequencies covered, which are equivalent to the range 40 to 500 mc for the model A discone. Wasteful high

angle lobes are noticed at the frequency equivalent to 500 mc. The model range technique permits measuring patterns with great accuracy under realistic conditions and the results differ in many respects from the idealized patterns usually encountered in textbook literature.

If a more narrow beam is desired near the horizon while retaining the 360 degree horizontal coverage, several discones may be stacked one above the other. While the band, over which the input impedance of such an array remains essentially constant, is narrowed by this procedure it is still enormous when compared with the useful bandwidth of arrays such as the stacked Franklin or the loop type radiators used in FM broadcasting.⁴

Operating Tests

The discone has a theoretical gain of about 1.8 over a dipole in its first half octave of frequency coverage. It was the purpose of the operating tests to determine what superiority, if any, could be noticed on the various ham bands within the model A discone's territory. A rig ending in a 4E27 with 200 watts input was used on the 6-meter band. An SCR 522 was put on 144 and 220 mc, with an APT 5 employed on 420. A 3-watt mobile unit for 420 was used for the mobile tests.

With regard to actual air contacts it is only fair to comment that ham radio in general is not set up as a research project. Hence the results to follow, because they are based on many "R" meter readings—each with its own peculiar characteristics of calibration and law characteristic—are necessarily qualitative instead of quantitative.

Comparison between the performance of the discone and four individual ground plane antennas cut for the middle of each band and carefully matched

(Continued on page 69)

⁴ Longitudinal and transverse arrays of discones as well as an "array" consisting of a discone feeding a hollow paper tube with a half power beam width of only 5 degrees cannot be described here but may be the subject of a later article.

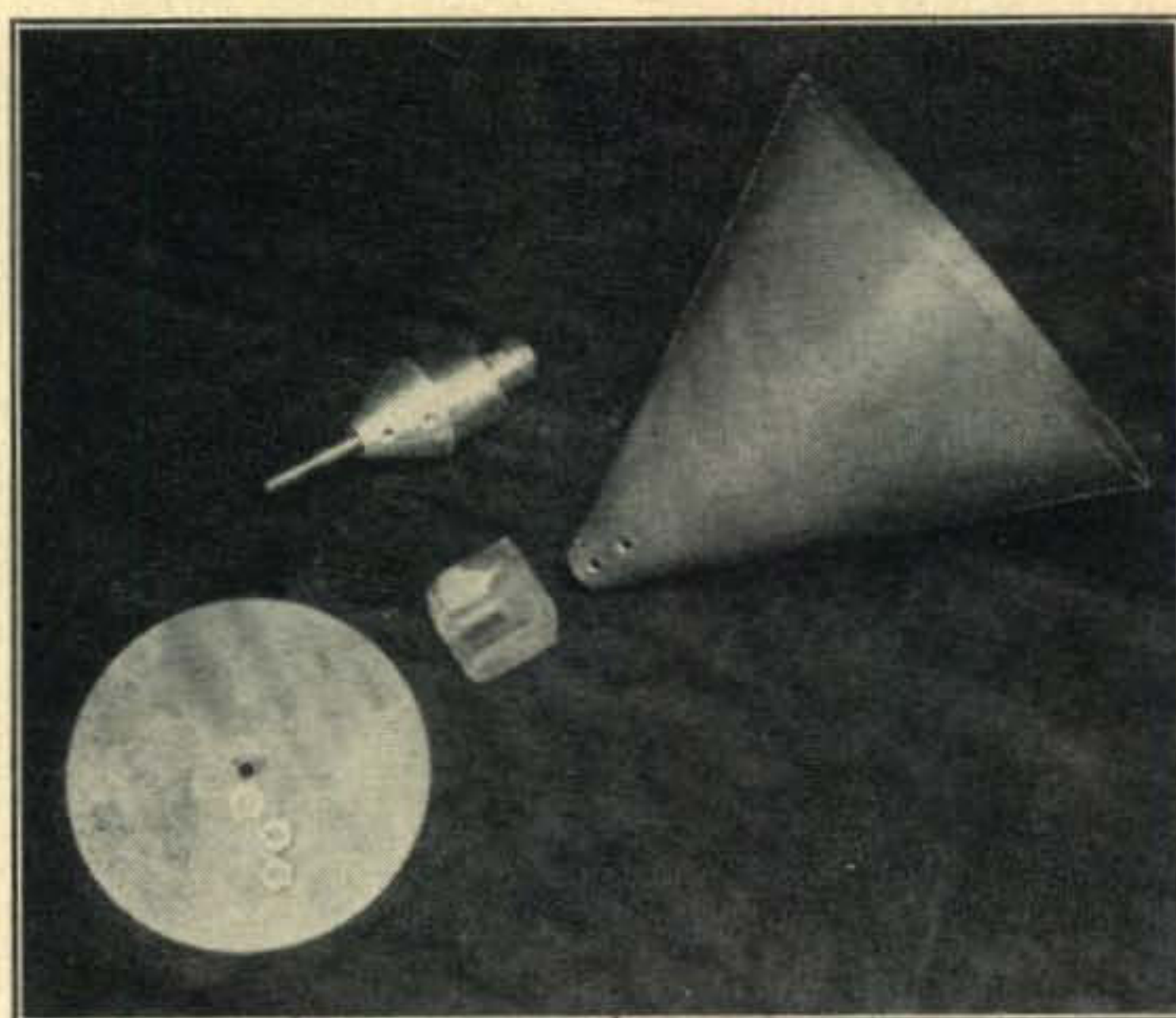


Fig. 8. An "exploded" view of the model B discone illustrating the simplicity of construction. A special flange, not shown, was welded to the base of the antenna for ease in mounting to an automobile roof.

³ Sinclair, Jordon, Vaughan, "Measurement of Aircraft Radiation Patterns Using Models," *Proc. I.R.E.*, Dec., 1947.

wild look in eye about to detune scared old Scratchi. Before he are getting any ideas like cutting off legs I are thinking fast and asking him why not bypassing me to ground.

He are evidently liking idea, as he are wrapping me well with wire, and connecting condenser to this and then to radiator. Then he turn on rig and go downstairs. This are working ok, I guess, as he are coming back and untying me. Needless to say, I am leaving hurriedly with instructions not to coming back until have grown cupple more inches.

I are sorry to be leaving so soon, as were about to try out antenna idea. Being he so high in air on top of building, couldn't Scratchi using metal framework of building for vertical antenna?

Respectively yours,
Hashafisti Scratchi

BC-624 NOISE LIMITER

[from page 25]

noise. Resistors need not be more accurate than 10% because a little clipping on occasional voice peaks is not objectionable in amateur communications. Distortion is so low that no provision has been made for cutting the limiter out of the circuit, or for adjusting the limiting level.

The 18,000-ohm resistor (R6) in the cathode lead from the 6B8 has no effect on detector and noise limiter performance. Its function is to provide a bias which delays the a.v.c. so that it does not act on weak signals. The amount of delay can be varied by changing the size of this resistor. In some receivers the a.v.c. diode load resistor, R8, is returned to ground rather than to the cathode. This more conventional connection should be retained. No changes were made in the audio amplifier other than adding a 6800- μ f condenser from the plate of the 6J5 (or 12J5) to ground. This serves to bypass the higher-pitched audio components of input noise which previously had been attenuated by the audio transformer.

DISCONE

[from page 15]

with shunt coaxial transformers to the RG 8/U line were requested from stations worked. By "carefully matched," we mean actually measuring the voltage standing wave ratio with a laboratory slotted line and matching until the line to the ground plane was as flat as it could be made. No matching of any kind was used on the discone at any of the frequencies used.

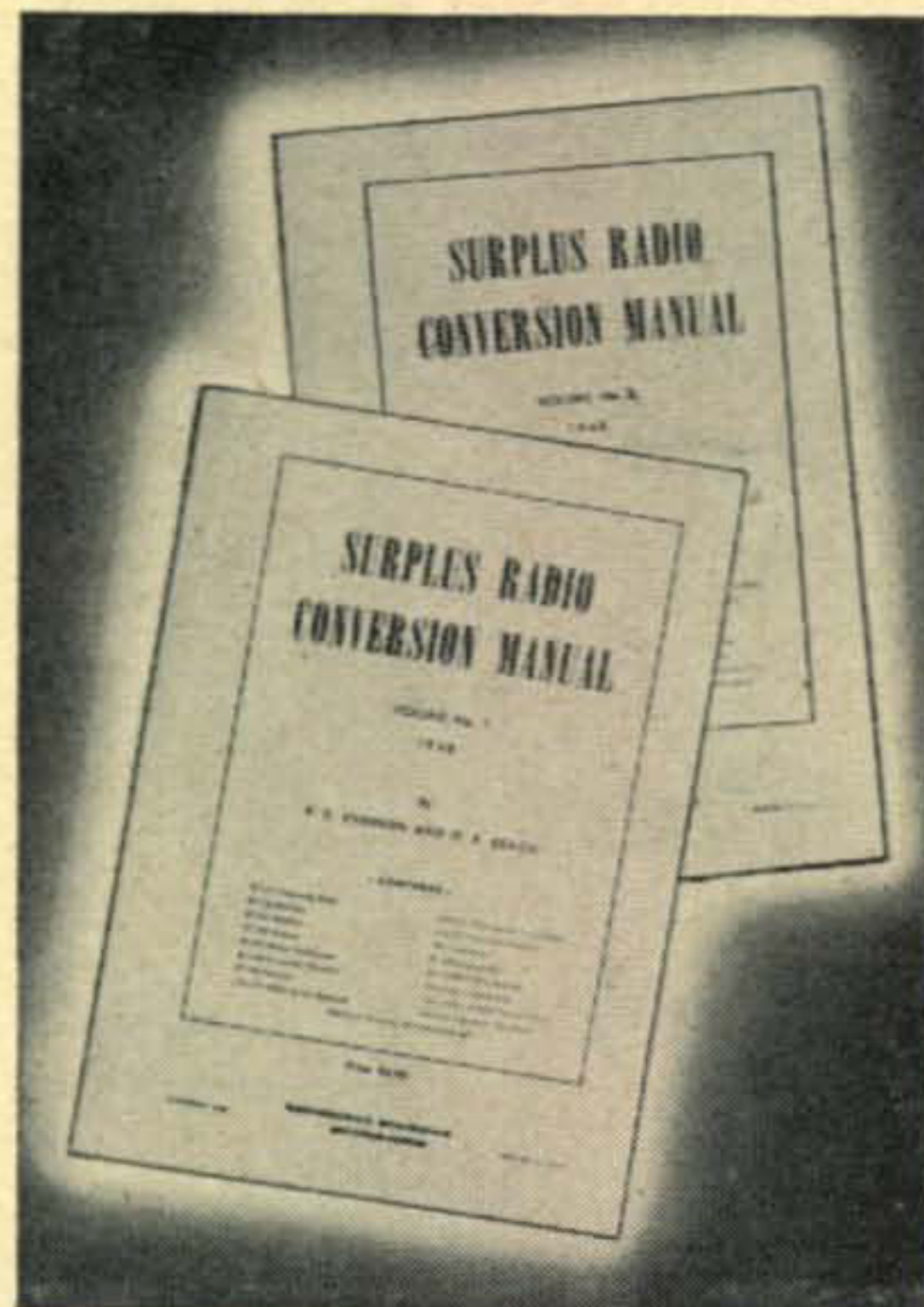
Out of twenty-two contacts made, nineteen reports gave the discone a 2 to 3 "R" advantage; one station called it a draw, and two other reports (on the three-quarter meter band) gave the discone anywhere from 3 to 5 R-units greater signal strength but had to be reluctantly discarded because the stations concerned were estimating by ear, not meter.

The smaller version of the discone shown mounted on an automobile top (model B, Fig. 5) was

outstanding radio texts

SURPLUS RADIO CONVERSION MANUAL IN TWO VOLUMES

THE
ONLY
BOOKS
OF
THEIR
KIND



Here is a set of reference data which has become standard for the most commonly used items of surplus electronic equipment. All conversions are practical and yield a useful item of equipment; all have been proven by testing on several units. Listed below are the many worthwhile items included in these helpful, unusual reference books.

VOLUME I

BC-221 Frequency Meter
BC-342 Receiver
BC-312 Receiver
BC-348 Receiver
BC-412 Oscilloscope as a test scope or as a television receiver
BC-645 420-Mc. Transmitter/Receiver
BC-453A Series Receivers
BC-457A Series Transmitters
SCR-522 144-Mc. Transmitter/Receiver
TBY Transceiver with Xtal Control
PE-103A Dynamotor
BC-1068A V-h-f Receiver
Electronics Surplus Index
Cross Index of VT-Number tubes

VOLUME II

ARC-5 and BC-454 Rcvrs for 28-Mc.
ARC-5 and BC-457 Tx for 28-Mc. Mobile
ART-13 and ATC Transmitter
Surplus Beam Rotating Mechanisms
Selenium-Rectifier Power Units
Hi-Fi Tuner from BC-946B Receiver
ARC-5 V-h-f Transmitter
GO-9 and TBW Transmitters
9-Watt Amplifier from AM-26
TA-12B and TA-12C Transmitters
AVT-112A Transmitter for Aircraft
BC-375 and BC-191 Transmitters
Model LM Frequency Meter
Primary Power Requirements Chart
ARB Receiver Diagram Only

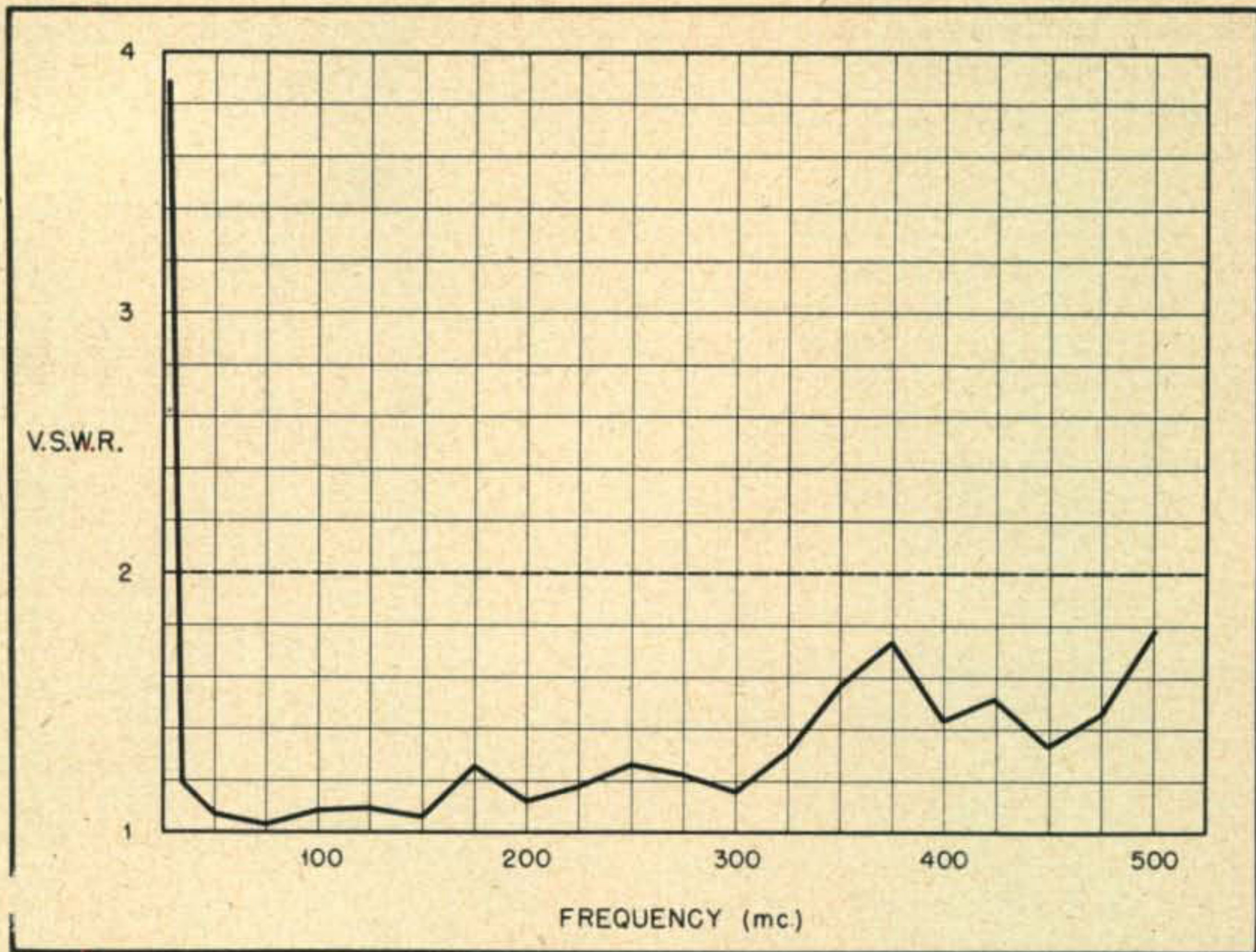
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Fig. 7. Voltage standing wave ratio existing in a 52-ohm coaxial line for model A discone. A v.s.w.r. magnitude of 2 represents only 3 per cent power loss due to impedance mismatch. Measurements were made on a laboratory slotted line.



necessary in order to test the antenna for suitability under mobile conditions. Operation was in the 420-mc band. Only two schedules could be arranged between the mobile unit and the home station in the time allotted for mobile operation. In both instances contact over a 12 mile path could not be established with ground plane antennas being used at both ends of the circuit. After a five minute call the home sta-

tion switched to the model A discone and was heard about Q3 R3 by the car. The mobile unit then tied in its discone and the signal was Q5 R4. The least that can be said from the above results is that the discone looks like a good, efficient antenna for members of the fraternity who do not desire a roof bedecked with an antenna for each v.h.f. band they operate in. For the experimenter who wishes to

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work with combinations of discons, possibilities appear extremely bright.

A point of interest about the mobile installation is that the base of the discone is welded to a flat ring of .064 brass. This ring is drilled and tapped for 12 type 10-32 screws which go directly into the car top which then acts as an excellent ground plane. Little change in the input impedance results when this is done, but the radiation pattern changes slightly. In this case a lowering of the major lobe was noticed. No attempt was made to secure permission for transmissions in the Citizens Band, although voltage standing wave measurements were carried out to 500 mc and, as can be seen from the curve, *Fig. 7*, predict excellent results for a band many hams will probably be tempted to try.

Construction Notes

Several suggestions for construction of a discone are given in *Figs. 2* and *6*. Due to the fact that the alternative designs in *Fig. 6* are only approximations of a solid surface they will not perform as efficiently over the higher range of frequencies as the models shown in *Fig. 2*. These sketches show, however, how simply the antenna can be made. In one case a "jury rigged" discone (*Fig. 6*) was constructed and put on the air in less than twenty minutes. It is recommended that if a permanent installation is contemplated that the builder pay the slight charge for having the inner support cone machined by a local shop. The author's model A antenna cost a total of \$25.00; this cost covered all raw materials from surplus sheet aluminum and bar stock to the machining fee. Wind loading is considerable on a structure offering as much surface as the discone, therefore a very rigid guying system or tower is suggested when mounting the antenna permanently more than a few feet above the roof.

DUAL CONVERSION SUPER

[from page 23]

capacity can be used across the coil for the same purpose, if desired.

The pitch control is an air trimmer of approximately 35 μmf maximum capacity. Actually, it is a standard 50- μmf air trimmer from which two stator and three rotor plates were removed, leaving nine plates in all. In order to avoid trouble from b-f-o harmonics, the pitch control condenser is mounted directly under the b-f-o coil so that its stator lead can be made as short as possible. A $\frac{1}{4}$ inch brass shaft and a pair of flexible couplers are used to couple the trimmer shaft to a bearing assembly mounted on the panel. In wiring the second i-f and detector circuits, be sure to keep all components close to the chassis to allow clearance for this shaft.

The send-receive switch, *SW*₄, is a double-pole-double-throw toggle switch, one pole of which is used to apply 117 volts a.c. to a pair of terminals on the rear of the chassis to operate antenna and transmitter relays in the "send" position. The other pole grounds the proper terminals of the gain control potentiometers in the "receive" position, and

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MACK SEYBOLD, W2RYI*

If you've been looking for an antenna to feed with a flat line on all bands from 20 meters through 6 meters without switches or tricks, here's the answer.

SUMMER IS A WONDERFUL TIME to crawl out of the basement into the sunlight to work on antennas. I was able to make that metamorphosis last summer, so if any of you pale-faced, hollow-eyed brass-pounders and microphone addicts plan to emerge from your winter haunts and enjoy the benefits of the great outdoors in the 1950 antenna season, I'd like to recommend a new and healthy antenna prescription.

The construction work on this new antenna will keep you out in the sun long enough to acquire a healthy tan, and the results of your efforts will be an amazing radiation system that performs the way amateurs have wanted antennas to perform since the days when Maxwell was a mathematician and not Jack Benny's automobile. As a matter of fact, Maxwell predicted what radio waves could do, but he didn't tell how they could do it. He certainly didn't dream up the discone—it took almost a century to get around to that development—but he undoubtedly would be pleased to know that at last there is available a method of coupling a radio signal to the ether in a clean-cut, efficient and fool-proof manner.

The discone is an antenna that has a low angle of radiation, presents a natural impedance match to a 52-ohm line over a 10:1 range of frequencies, and has a symmetrical configuration which minimizes the occurrence of standing waves on the outside of a coax feeder. The impedance-matching feature is probably the most remarkable thing about the discone. It certainly should please the amateur who has had difficulty obtaining low standing-wave ratios on transmission lines and antenna-coupler links. Actually, with a discone antenna, coax feeder, and low-pass filter, antenna couplers can be dismantled and forgotten.

Amateur Wizards

Sometimes amateurs have to become magicians with stubs, shorting bars, gamma-matches, T-matches, delta-matches, field-strength indicators, s.w.r.-bridges, grid-dip meters, loading coils, hack-saws, and crowbars to get an antenna system to work well on one frequency. The discone doesn't require any of the cut-and-try magic to make it work perfectly on *any* frequency. From the time the first hole is drilled until the last nut is tightened, the only measuring equipment needed is a ruler, and all that remains to be done after that is to turn on the transmitter.

An article by Joe Boyer, W6UYH, started the amateurs on this discone deal. The July, 1949, *CQ* presented the electrical theory, and it described the construction of high-frequency discones. After reading Joe's article, I was interested in trying the idea at lower frequencies and determining if wire and aluminum angle pieces could be used instead of the sheet metal prescribed for the original discones.

* c/o Tube Department, Radio Corporation of America, Harrison, N. J.

I also wanted to have an antenna for 10, 11, and 20 meters that would radiate and present a reasonably constant load to the transmission line in the television spectrum in order to study the effectiveness of low-pass filters for TVI. Some of the television interference tests also required a reduction of r.f. fields in the vicinity of the transmitter, so the symmetrical discone, promising a minimized standing-wave condition on the outside of the coax, looked like the answer to the antenna problem.

Antenna Project

With encouragement from Joe Boyer by correspondence and with the approval of the *XYL*, I assumed responsibility for the top of the garage, and

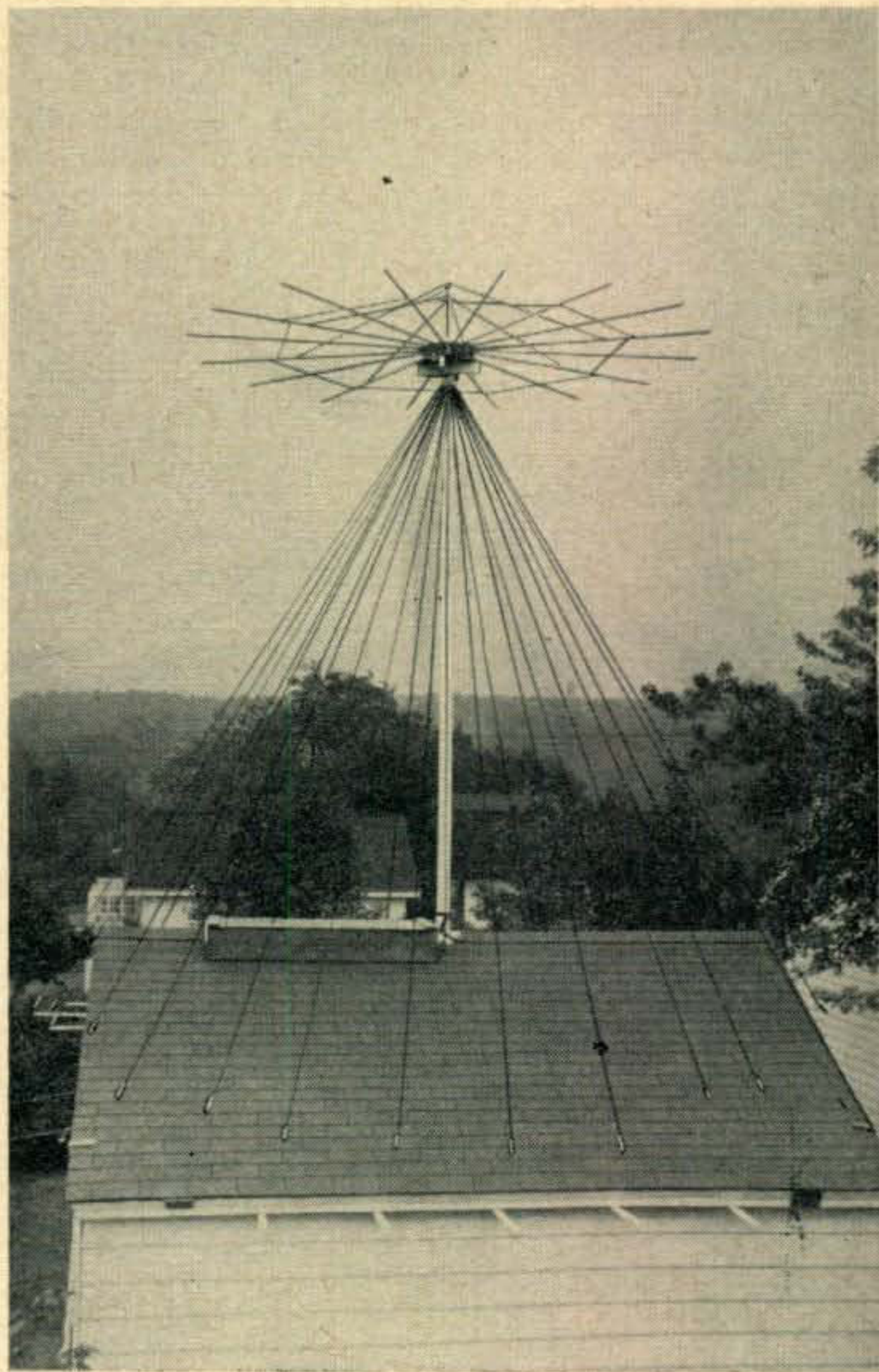


Fig. 1. Side view of the 11-mc discone. The disc is made of angle aluminum, and the cone consists of 28 wires which are fastened to specific points on the garage roof and to outriggers. The 52-ohm coax feeder runs up the mast and terminates at the tip of the cone and the center of the disc assembly.

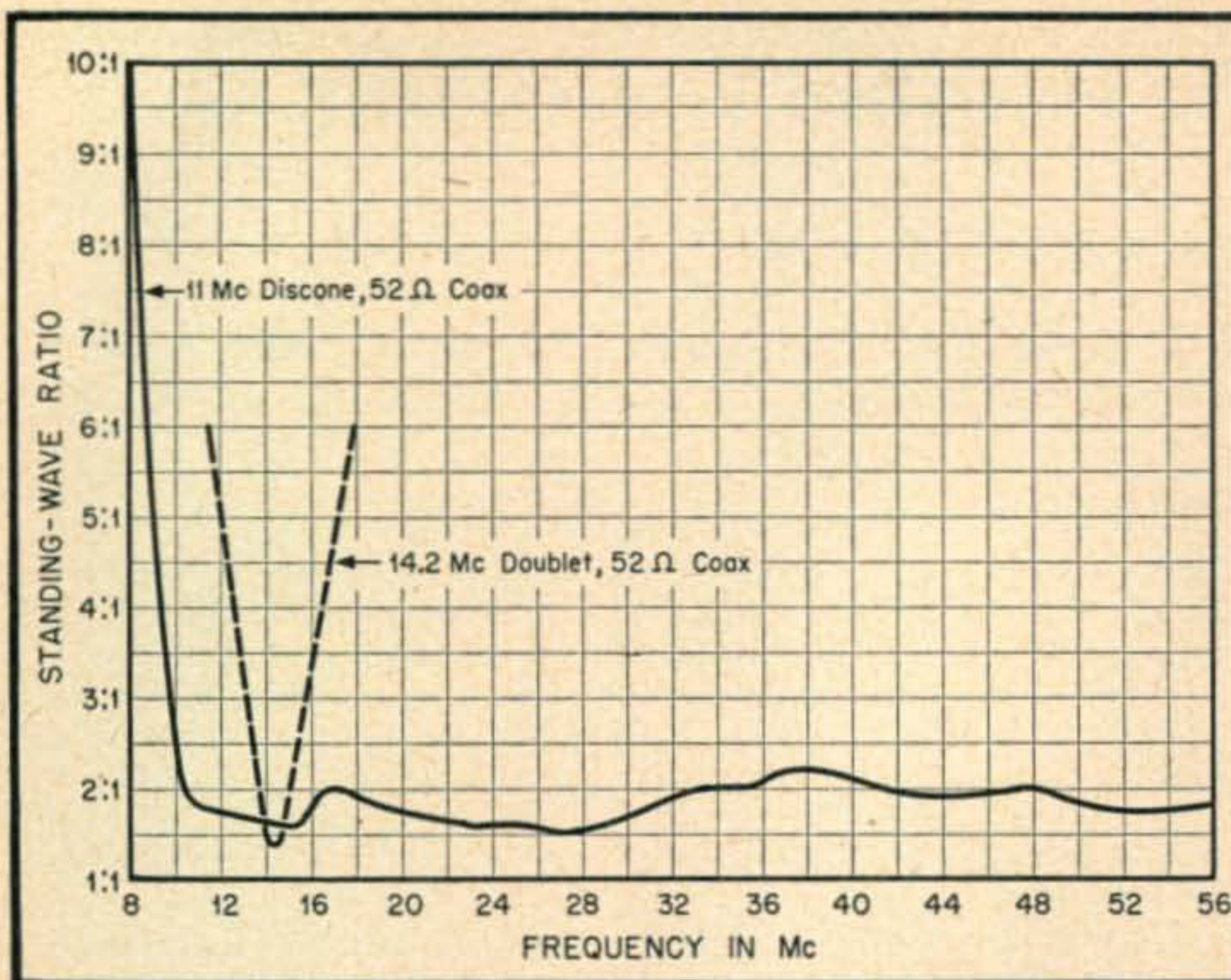


Fig. 2. A plot of standing wave ratio vs. frequency of the l.f. discone when fed with 52-ohm coax line. The broken line is the s.w.r. curve of a conventional 14-mc doublet.

began to work on the new antenna. There was just enough of the unknown and the element of uncertainty in the project "Monstro Discone" to make the adventure in the back yard during the summer of 1949 interesting and exciting. The results, however, were even more exciting, because when the antenna was finished it surprised everyone, including myself, by working perfectly, and it has been on the air ever since.

The specifications for the 11-mc discone are as follows:

Length of cone wires ..	21'
Disc diameter	14' 6"
Cone-to-disc spacing ...	1'
Cone apex angle	60°
Diameter of cone base ..	21'
Height of cone	18'

This discone is the one shown in Fig. 1. It was cut for 11 mc because of an uncertainty in the safety factor required for good results at 14 mc. It is obvious from the s.w.r. curve, Fig. 2, that a much smaller safety factor is required.

For 20 meters, a 13.5-mc cut-off frequency should



Fig. 3. The 100-mc discone, as arranged for photographing by the jr. op, Susie. The aluminum disc is 20' in diameter, and the 60° cone is formed of 48 wires, each 37' long. This bird cage is permanently installed in the attic and is used mainly for 2-meter work.

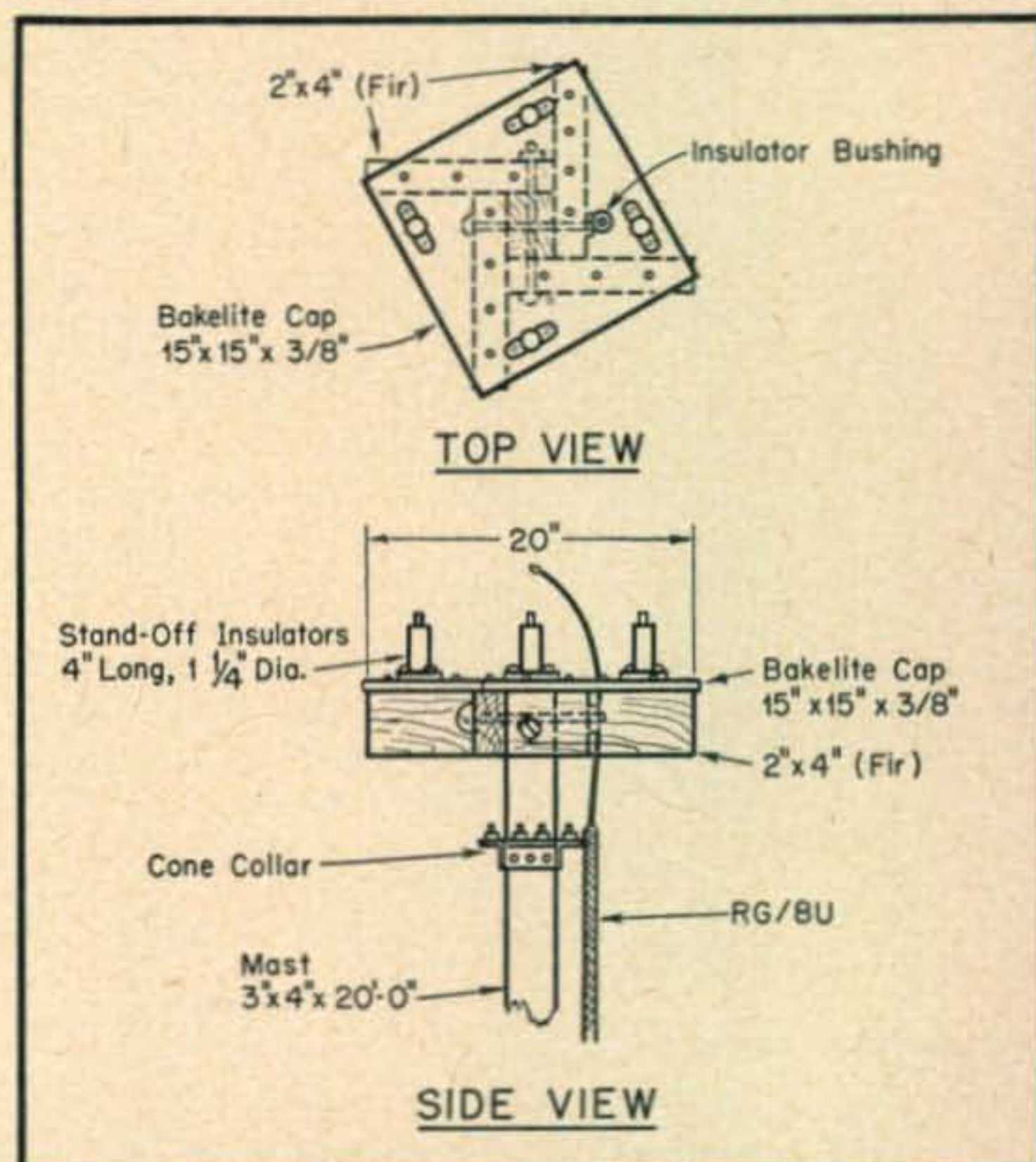


Fig. 4. The insulator assembly. The disc of the discone fits over the bolts in the tops of the standoff insulators. The angle-brass cone collar is fastened to the mast with wood screws.

be adequate, so the dimensions for a 20-meter discone, along with 15- and 11-meter antennas are given in the following table.

Table I

Cutoff frequency	13.5 mc	20.5 mc	26. mc
Length of cone wires	18'	12'	9' 6"
Disc diameter	12'	7' 10"	6' 2"
Cone-to-disc spacing	10"	6"	4"
Diameter of cone	18'	12'	9' 6"
Height of cone	15' 7"	10' 5"	8' 3"
Amateur bands	20, 15, 11, 10, 6, 2 meters	15, 11, 10, 6, 2 meters	11, 10, 6, 2, 1.5 meters

Joe Boyer's original article covers the discons for 50 mc and upwards, so the dimensions will not be given here. Fig. 3, shows a 100-mc model that now hangs from the rafters in the attic at W2RYI. Even though it is an "inside" antenna, it gets identical reports on comparison tests with an outside antenna cut for 2 meters. The "outside" radiator is a vertical, omni-directional antenna having three half-wave sections that are in phase. My 100-mc discone has 48 wires in the cone and an aluminum plate for the disc.

11-mc Discone

Open-mesh design simplifies construction of large discons and offers low wind resistance. One-third of the cone elements in the 11-mc discone are made of #14 Copperweld. The rest of the cone elements are solid copper wire, but they all act as guy wires in addition to their primary function of radiating r.f. power. Since there are 28 of these elements, the mast is held firmly and does not sway in the wind. In the January "hurricane," the wind blew down our television antenna, but the discone mast weathered the gale without a tremor.

The disc assembly is also constructed to offer minimum wind resistance. A sheet-metal disc 14.5 feet in diameter would require extensive reinforcement, strong anchorage, and would exert a tremendous force on the mast in a high wind. The disc must also be insulated from the mast and cone, so any dielectric used to support the disc would have to be capable of withstanding great stress and strain.

By using 16 radials instead of sheet metal for the disc, the electrical properties of a continuous surface are approached, but the wind resistance of the disc is minimized. Strong winds do produce torsion at the center of the disc, and the mast twists a few degrees, but with the base of the mast held firmly in place, the twist distributes itself throughout the length of the mast, and no immediate damage can be done. In time this action might produce longitudinal cracks in the wood, but in the nine months that the 11-mc discone has been in operation, no fissures have been found.

Because of the radial construction of the "disc" and consequent minimized wind resistance, stock stand-off insulations may be used to support the disc assembly. Four porcelain insulators 4" long and 1 1/2" in diameter, are bolted to a bakelite mast cap. The cap (Fig. 4) is fastened with wood screws to four short 2 X 4's which are nailed to the top of

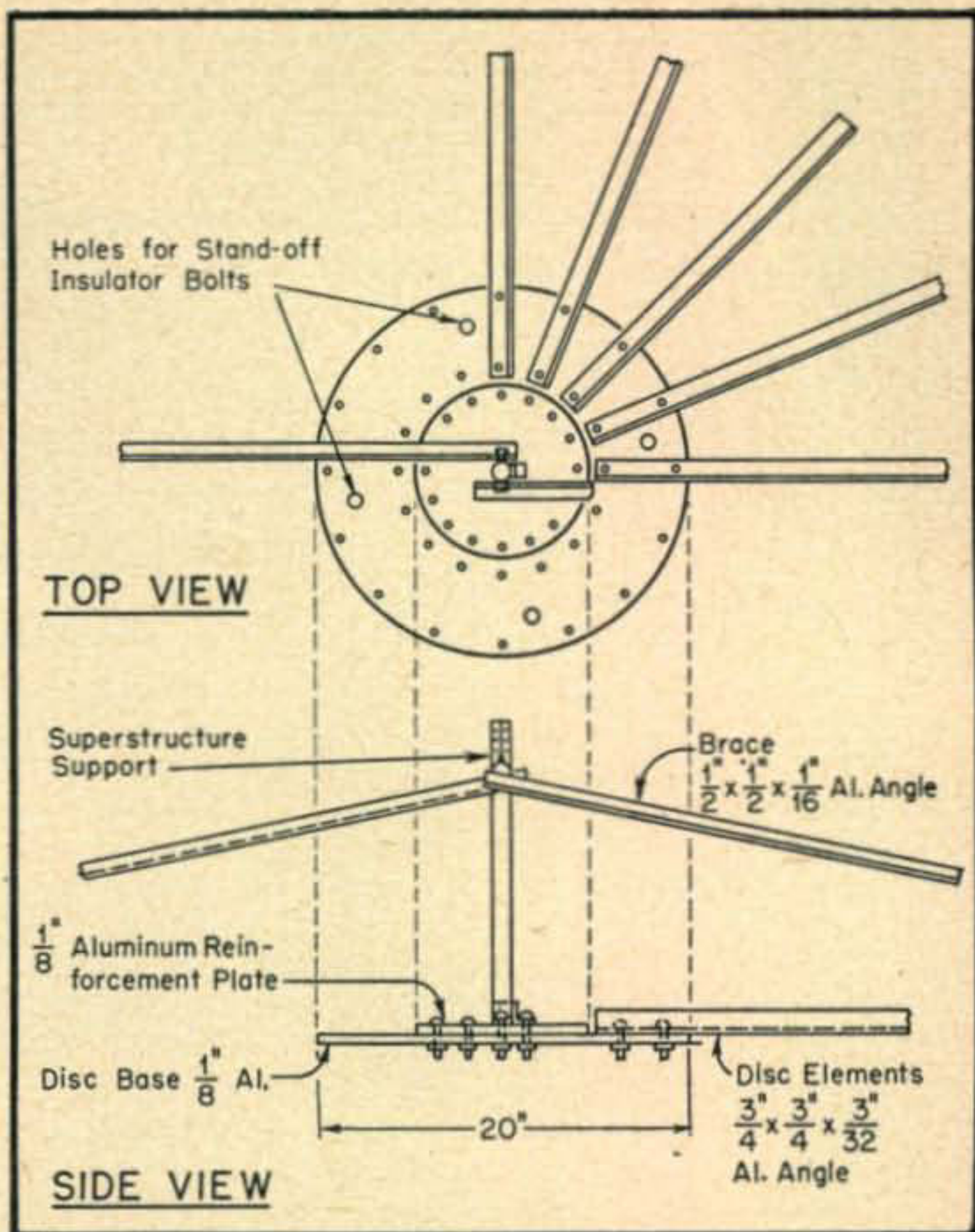


Fig. 5. Views of the center portion of the disc, partially assembled. Five of the 16 disc elements and two of the eight superstructure braces are shown.

the mast. This "insulating" structure makes a firm anchorage for the disc assembly which is bolted to the tops of the four porcelain insulators.

Assembling the Disc

The disc structure can be assembled on the ground. An aluminum plate, 1/8" thick and about 20" in diameter, is drilled to take the radials, the insulator bolts, and the superstructure support. The superstructure support is a vertical member seated on top of the disc at the center, and it is held in place by two angle brackets which are bolted to a reinforcement plate (Fig. 5). After the aluminum-angle radials have been bolted loosely in place, the horizontal struts are added, then all bolts are tightened. Next, 8 aluminum-angle braces

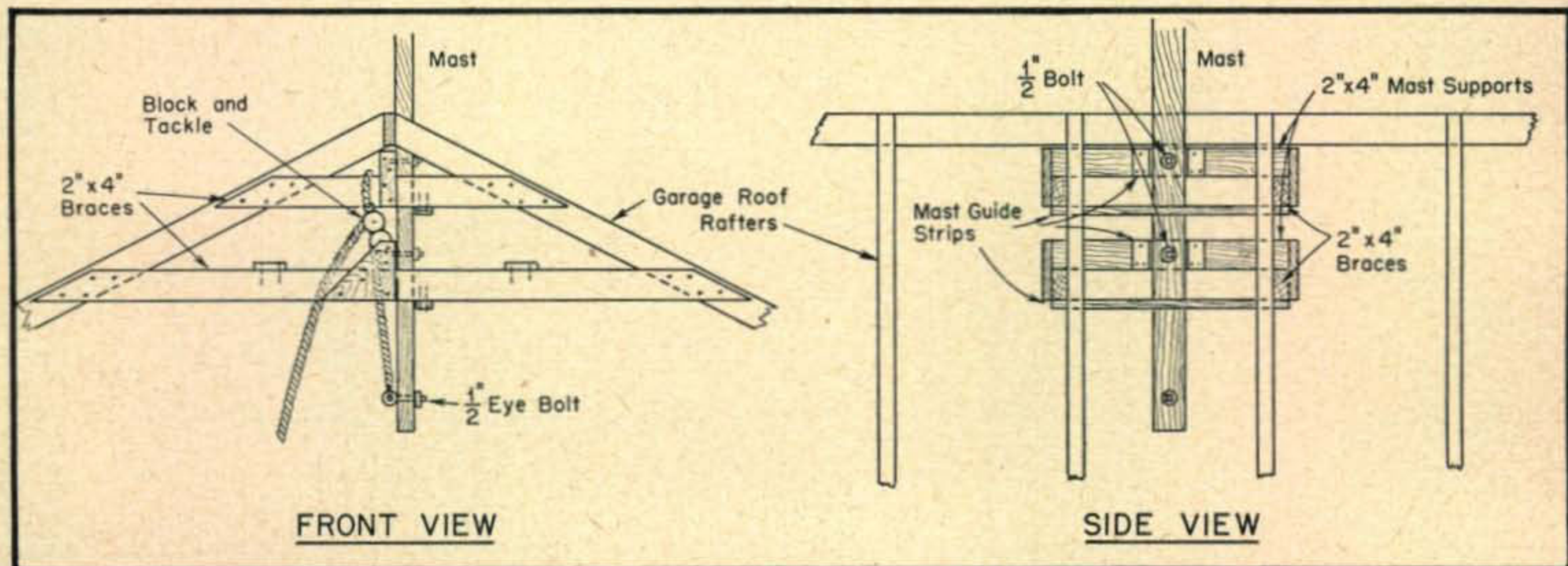


Fig. 6. Mast support inside the garage. The roof firring and shingles are not shown in order to simplify the drawing.

are bolted between the top end of the super-structure support and the midpoints of alternate radials. The intervening radials are connected from their midpoints to the tip of the super-structure support with galvanized-iron guy wires. The entire disc assembly is rigid and light, and can be lifted by one man into position on the insulators at the top of the mast.

Mast and Feeder

The mast is a fir 3 X 4, 20 feet long. It passes through a hole in the center of the garage and is bolted to a structure inside the garage (Fig. 6). A block and tackle slung from the same structure makes it possible to raise and lower the mast. At its lowest position, the top of the mast can be reached from a step ladder placed on a roof platform that can be seen in Fig. 1. The step ladder is comfortable to work on when mounting the disc and attaching the cone wires.

A collar, made of angle brass, is screwed to the four sides of the mast at a position one foot below the disc. Around the periphery of the collar are 14 bolts (8-32s), each of which secures two cone wires. The collar also has one bolt to secure the lug that is soldered to the outer conductor of the coax feeder. Because the collar is the point at which the transmission line terminates, an extension made of #12 copper wire is soldered to the center conductor of the coax. This extension passes through

a ceramic sleeve set in a hole in the bakelite cap, and then goes directly to a bolt in the center of the disc. Details are shown in Fig. 4.

Cone Wires

Each of the cone wires is 21 feet long. Each has a strain insulator at one end, the other end having been bolted to the mast collar. The insulator terminates the radiating portion of each cone element, but wire extensions connected to the insulators are used to fasten the cone elements to the garage. Actually, some of the cone elements must be fastened to outriggers in order to establish a perfect conical structure.

The exact position and length of each outrigger, and the tie points on the garage for all the rest of the cone elements, can be obtained from a three-view drawing of the structure. Cut-and-try methods are also possible, but it saves time if the locations of all the tie-points have been determined in advance. Fig. 7 shows the drawing used to locate the 11-mc discone on the top of our double garage.

Before the cone elements are fastened to the outriggers, the mast is raised and bolted in position. Aluminum foil of the type used by the XYL in the kitchen is cemented to the mast and roof with asphalt caulking compound to make a water-proof joint. Foil is advantageous because it will tear

(Continued on page 60)

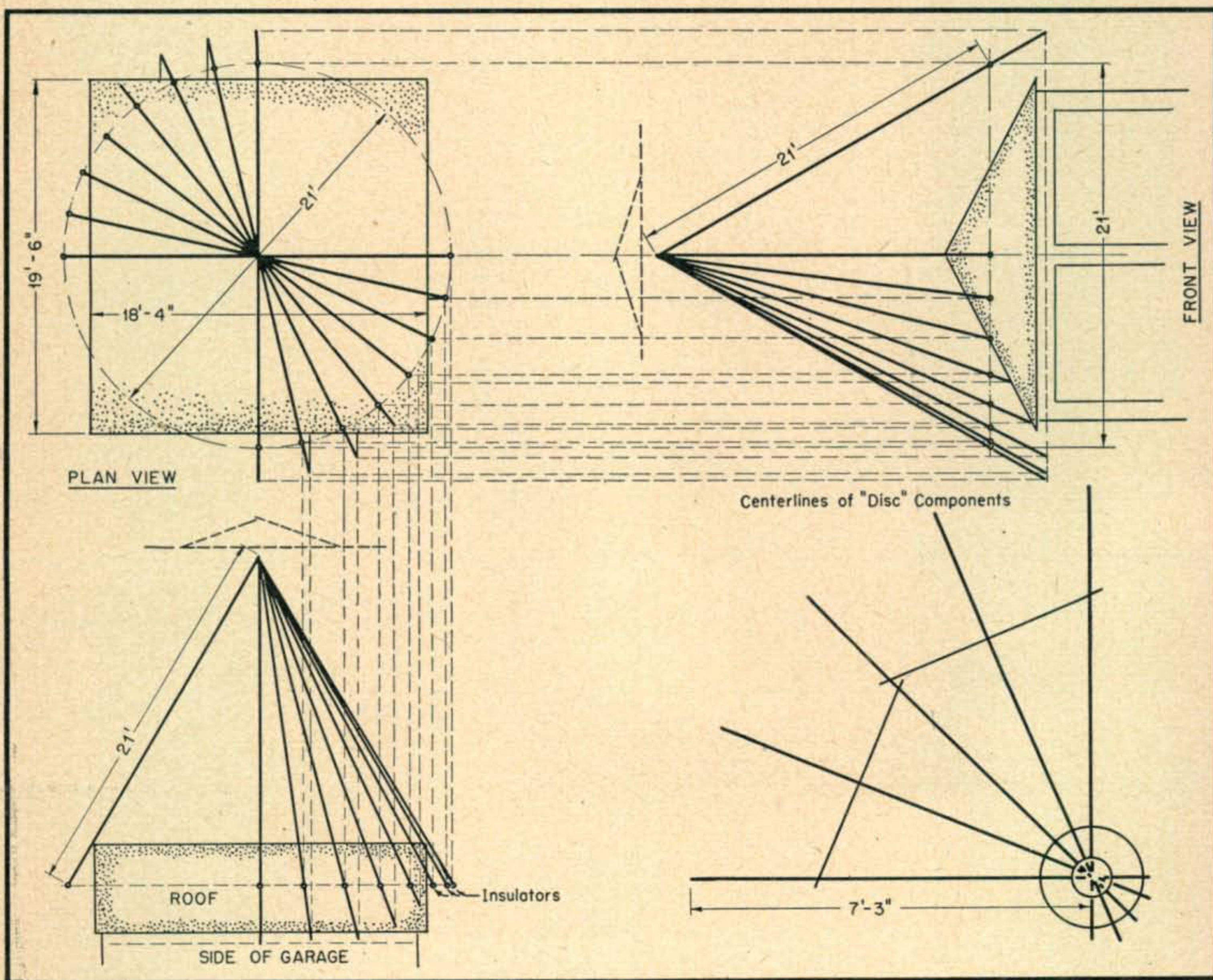


Fig. 7. Projection of the cone elements to establish position of the tie points and outriggers.

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LOW-FREQUENCY DISCONE

(from Page 16)

easily if the mast has to be lowered at a time when the roof is icy and inaccessible.

The cone elements are fastened with just enough tension to keep them from sagging, and then, alternating from side to side and from back to the front of the garage, they are tightened to guy the mast uniformly. The coax is then connected to the transmitter, and the system is ready for operation.

Feeder Systems

In order to keep the RG-8/U cable as far from the field of the discone as possible, I buried it at a depth of 10 inches for the 60 feet it traverses to the house. R.f. on the outside of the feeder is kept to a minimum, and no deterioration of the cable has been noticed thus far. A deeper ditch would have been dug if it had not been for the rocks. As far as transmissions are concerned, the coax can be strung eight feet above the ground with good results, but for the low-pass filter tests, the underground feeder operating into the discone presented an excellent, symmetrical load.

Results

The 11-mc discone was finished on Labor Day last year. Since then, numerous comparison tests have been run on 20, 10, and 2 meters. Generalizations from the data obtained indicate that the vertically polarized signal emanating from the discone is about 2-db stronger than a signal from a vertical dipole. Polarization is important on 10-meter ground-wave contacts, but it is only important that the receiving antenna and transmitting antenna be polarized the same way. If they are not in the same plane, as much as 40-db difference in signal strength can be found. The discone is a sure-fire target for signals from the mobile gang, and many enjoyable QSOs have been had over long ground-wave paths.

Evidence for the behavior of the discone at 29 mc in the range from 1000 to 1500 miles is conflicting. At times a horizontal dipole was 6 to 9 db better. At other times the discone was superior. On the long skip paths, however, the discone was always superior to a horizontal or a vertical dipole.

On 20 meters, polarization did not have as marked an effect over ground-wave paths as it did on 10, and comparisons with a horizontal dipole over short-skip, long-skip and DX paths always showed the discone to be the better radiator. After a month or more of such tests, I was convinced that the 20-meter dipole was superfluous, and took it down.

Six-meter tests have not been run, but some are planned in the near future. At 2 meters the 11-mc discone does radiate, but it is 10 db below the level of the "bird-cage" 100-mc discone. Loading is no problem at 144 mc because the S.W.R. is still reasonable at that frequency, but the large spacing between the disc and cone is probably the cause of the poor radiation pattern. Naturally, I use the 100-mc discone for 2-meter work.

The 11-mc discone will be used at W2RYI on 21 mc as soon as the 15-meter band it made available. When that important date arrives, the big discone will be the basic antenna for operations on 20, 15, 11, and 10 meters, and I don't think it's going to be too long before an 829-B will be feeding that buried coax in the long-neglected 6-meter band.

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But the discone—originated during World War II and re-discovered about

a year ago for CB use—comes awfully close to being that impossible “ultimate sky-wire.” It offers a near-perfect match to 52-ohm coax cable; an operating range of 10-to-1 in frequency (relatively unimportant for CB use but essential should you ever decide to go into ham radio or the commercial FM systems operating between 30 and 175 mc.); and freedom from any critical tuning adjustments.

In addition, because of our 20-foot limit on antenna height, the discone offers greater ground-wave range pos-

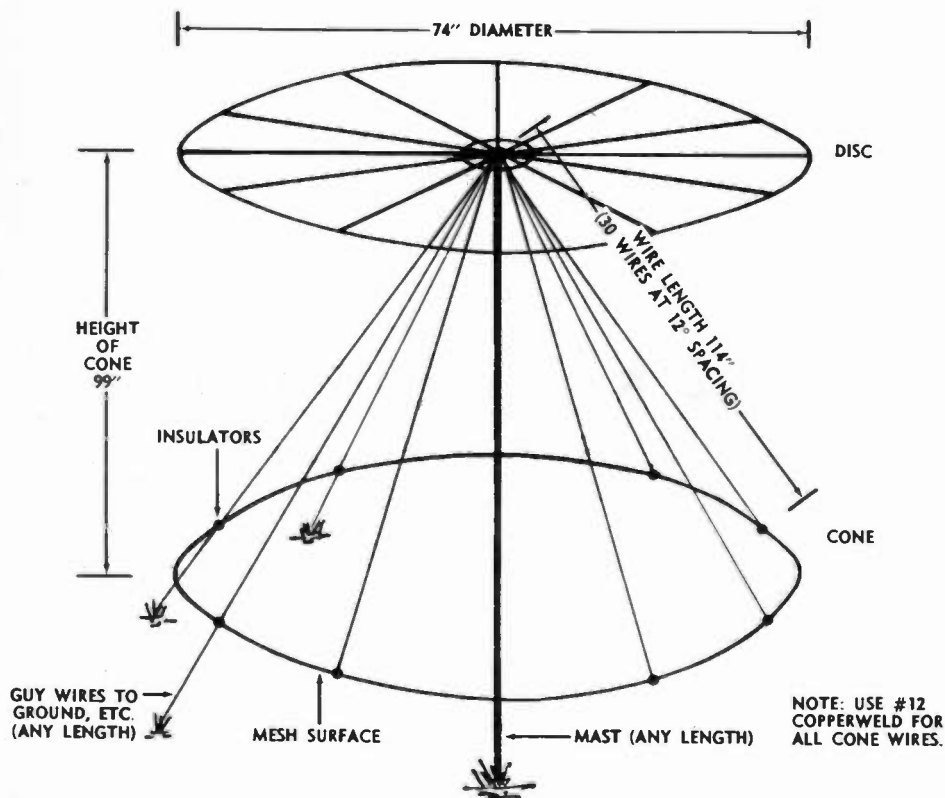


Figure 1. Discone For CB, Overall View.

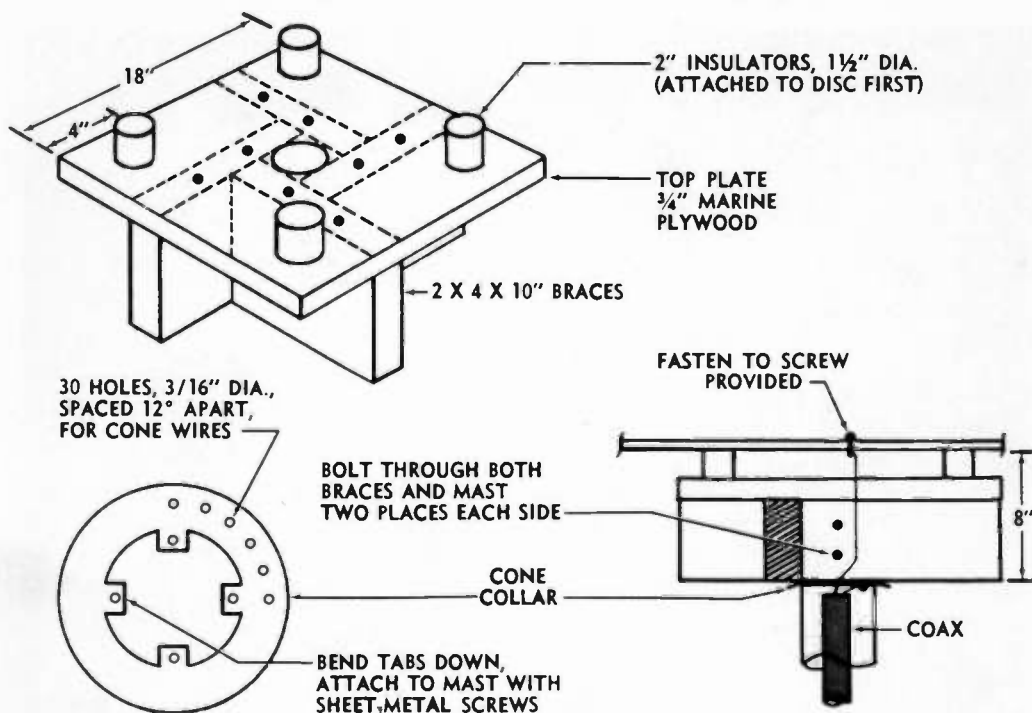


Figure 2. Insulator details.

sibilities than do many other vertically-polarized antennas. This comes about because its most effective portion is located right at the top of the pole; other designs have their most effective portions part-way down the mast which usually results in a closer "radio horizon."

By now, you're probably asking "Where can I get one of these gadgets?" As this is written, you can't but you can build one at a reasonable outlay of time and cash.

Before starting construction, though, it's best to know just what a discone antenna is and what it is supposed to do. Basically, the discone consists of an inverted (point to the sky) metallic cone with a large disc (also metallic) balanced on the point. The disc is really fastened firmly, and insulated, instead of balanced—but at any distance it looks like a balancing act (see Figure 1).

The coax feed line comes up inside the cone. The shield of the coax con-

nects to the cone, and the center conductor connects to the disc.

Thus, the cone becomes a continuation of the shield, while the disc becomes a reflector connected to the center wire.

In practice, outgoing RF energy hits the disc and is reflected out the open side of the affair. If the "slant angle" of the cone sides is correct, though, the outgoing signal can't tell what's happening to it and the SWR will be down to 1.0.

The important things electrically, then, are to keep the slant angle of the cone sides proper and to keep the top disc level. Good insulation between disc and cone at the center is also essential.

Mechanically, an 11-meter discone is quite an impressive array—and offers much, much wind resistance. If you built one out of solid sheet metal, the first breeze would tend to whip it away like a sail.

However, a fine-mesh screen looks to RF like a solid sheet of metal if

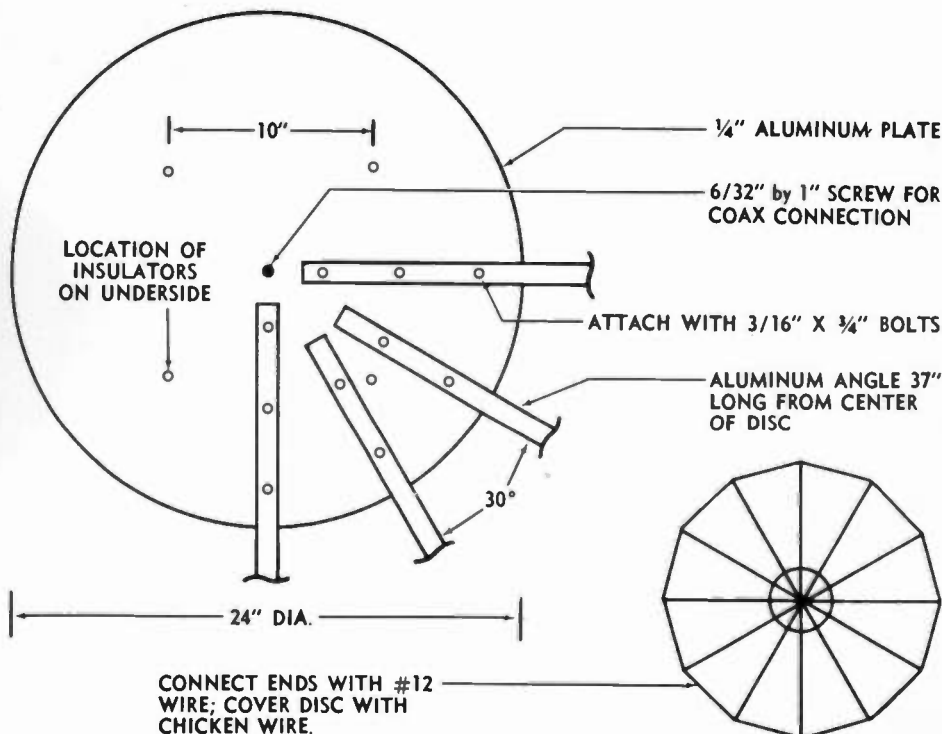


Figure 3. Details Of Disc assembly

—and *only* if—the spacing between conductors in the screen is small compared to the wavelength of the RF. This is the key to our construction.

For instance, a screen spacing of 0.01 wavelength is plenty close enough to look solid to RF. Yet at 11 meters this becomes a spacing of 0.11 meter or 4½ inches (approximately) so that you could use very coarse fencing mesh for lowest wind resistance.

Best results were obtained with a type of fencing usually called “chicken wire” screening. This has a hexagon screen pattern about an inch wide between conductors. You can use it for the surface of both the cone and the disc, cutting wind resistance to an absolute minimum.

However, the chicken wire is too flexible to stand up by itself. You must put a framework behind it for support. Wooden framing is okay, but aluminum angle stock is just as easy to work with and lasts longer.

The only really tricky part about the whole antenna is construction of the insulator that goes between the

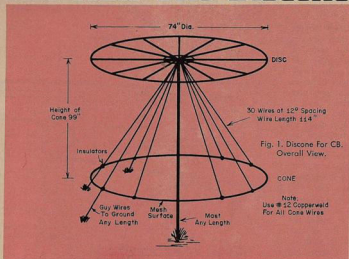
disc and the cone. It's shown in detail in Figure 2; follow the drawing closely and you won't go wrong.

Actual construction procedure is as follows: First, put up your mast. It can be any length between 9 feet and 19 feet. Next, fasten the insulator-and-guy-ring structure to the top of the mast. Now, connect the coax to the insulator-and-guy-ring assembly. Put together the disc assembly on the ground and get it into position on the insulator aloft (this may require some help.) Attach the guy wires to the assembly and secure them at anchor points selected so as to give the proper slant angle. Finally, cover the guy-wire structure with chicken wire, soldering the joints, and you're ready.

The disc assembly referred to above is shown in detail in Figure 3. It should be completely assembled on the ground and lifted to the top of the pole before securing to the insulators—otherwise, the affair will be too top-heavy.

When you're finished, hook the other end of the 52-ohm coax to your transmitter and fire up.

All Hail The Discone



CB's FORGOTTEN SUPER-ANTENNA

Discone is a word which strikes apathy in the minds of most CB'ers, but don't pass this article by if you're interested in hanging out a CB antenna which will put a wallop signal out for your base station. It isn't too difficult to build and the one outfit which was making these for CB'ers some years back no longer seems to be around. First you must ask yourself if you're really looking for a smashing signal.

Of course you are—just like everybody else. And no matter how many chunks of metal and wire you hang in the air, you're never going to stop looking for that *ultimate* antenna, because it will never be built. Base station antennas have too many different requirements for any single design ever to be "the ultimate."

But the discone—originated during World War II and re-discovered for a short period in 1961 for CB use—comes awfully close to being that impossible "ultimate sky-wire." It offers a near-perfect match to 52-ohm coax cable; an operating range of 10-to-1 in frequency (relatively unimportant for CB use but essential should you ever decide to go into ham radio or the commercial FM systems operating between 30 and 175 mc.); and freedom from any critical tuning adjustments.

In addition, because of our limit on antenna height, the discone offers greater ground-wave range possibilities than do many other vertically-

polarized antennas. This comes about because its most effective portion is located right at the top of the pole; other designs have their most effective portions part-way down the mast which usually results in a closer "radio horizon."

By now, you're probably asking "Where can I get one of these gadgets?" As this is written, you can't but you *can* build one at a reasonably out-lay of time and cash.

Before starting construction, though, it's best to know just what a discone antenna is and what it is supposed to do. Basically, the discone consists of an inverted (point to the sky) metallic cone with a large disc (also metallic) balanced on the point. The disc is really fastened firmly, and insulated, instead of balanced—but at any distance it looks like a balancing act (see Figure 1).

The coax feed line comes up inside the cone. The shield of the coax connects to the cone, and the center conductor connects to the disc.

Thus, the cone becomes a continuation of the shield, while the disc becomes a reflector connected to the center wire.

In practice, outgoing RF energy hits the disc and is reflected out the open side of the affair. If the "slant angle" of the cone sides is correct, though, the outgoing signal can't tell what's happening to it and the SWR will be down to 1.0.

The important things electrically, then, are to keep the slant angle of the cone sides proper and to keep the top disc level. Good insulation between disc and cone at the center is also essential.

Mechanically, an 11-meter discone is quite an impressive array—and offers much, much wind resistance. If you built one out of solid sheet metal, the first breeze would tend to whip it away like a sail.

However, a fine-mesh screen looks to RF like a solid sheet of metal if—and *only if*—the spacing between conductors in the screen is small compared to the wavelength of the RF. This is the key to our construction.

For instance, a screen spacing of 0.01 wavelength is plenty close enough to look solid to RF. Yet at 11 meters this becomes a spacing of 0.11 meter or 4½ inches (approximately) so that you could use very coarse fencing mesh for lowest wind resistance.

Best results were obtained with a type of fencing usually called "chicken wire" screening. This has a hexagon screen pattern about an inch wide between conductors. You can use it for the surface of both the cone and the disc, cutting wind resistance to an absolute minimum.

However, the chicken wire is too flexible to stand up by itself. You must put a framework behind it for support. Wooden framing is okay, but aluminum angle stock is just as easy to work with and lasts longer.

The only really tricky part about the whole antenna is construction of the insulator that goes between the disc and the cone. It's shown in detail in Figure 2; follow the drawing closely and you won't go wrong.

Actual construction procedure is as follows: First, put up your mast. It can be any length be-

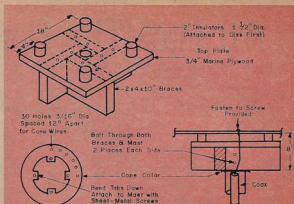


Fig. 2. Insulator Details.

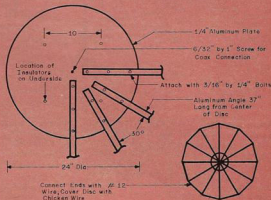


Fig. 3. Details Of Disc Assembly.

tween 9 feet and 19 feet. Next, fasten the insulator-and-guy-ring structure to the top of the mast. Now, connect the coax to the insulator-and-guy-ring assembly on the ground and get it into position on the insulator aloft (this may require some help.) Attach the guy wires to the assembly and secure them at anchor points selected so as to give the proper slant angle. Finally, cover the guy-wire structure with chicken wire, soldering the joints, and you're ready.

The disc assembly referred to above is shown in detail in Figure 3. It should be completely assembled on the ground and lifted to the top of the pole before securing to the insulators—otherwise, the affair will be too top-heavy.

When you're finished, hook the other end of the 52-ohm coax to your transmitter and fire up.

THE H.F. DISCONE

by Henry Randall — ZS5HF.

In these modern times there must be very few of us who have not at least been to a reasonable sized airport at some time or another and being good Hams, we will have kept our eyes open and will have noticed that spidery looking device perched near the control tower — that spidery looking device is not a lightening arrestor but a broad-band antenna.

Most people associated with radio communication will be aware that UHF and VHF bands tend to be quite wide — spreading over many megahertz. For example the normal aircraft VHF band stretches from somewhere about 110 Mhz to about 138 Mhz and the UHF bands stretch in a similar fashion. Naturally conventional antennas with a bandwidth of a few hundred Khz would be of little value and, therefore, attention has been given to the design of a "broad-band" antenna. The result of research has produced a number of interesting configurations, but one of the simplest is the "DISCONE". This antenna features extreme simplicity of construction an exceptionally low radiation angle excellent omni directional propagation and up to 10:1 bandwidth. The possible disadvantage is that the Discone has a unity gain. However, don't let this put you off because some mighty fine contacts have been made with a ground plane.

As the name implies, the Discone comprises a "disc" or "hat" and a cone — the "disc" portion is the "hot" leg and the cone is at ground potential. Being an unbalanced antenna it is ideal for coax feed and if the dimensions below are followed the feed impedance will be an almost perfect match to 52 ohm coax (RG 8/U / UR67 etc). On the assumption that the lower design point is 7 Mhz the upper limit will be close to 70 Mhz so all bands can be covered, 40 thru' 6, with an SWR of less than 1.5:1 to boot.

Another feature of the Discone is that the height of the radiator is not a determining factor in system performance — the height is actually determined by calculation but the notable point is that for a dipole at the same height the radiation angle would be close on 90° — virtually useless.

Possibly the discone on 40 metres is a little large about the skirt but for 20 or 15 it could be a definite proposition more especially as you could cover way above 2 metres with a single antenna.

References to the sketches will show the principal constructional points. Figure 1 shows the discone in "skeleton" form. The dimensions for L.F. cut off frequencies of 20: 15: and 10 are as follows :

20 Metres

D = 12 feet
L = 18 feet
S = 10 feet
R = 18 feet
H = 15 feet 7 inches

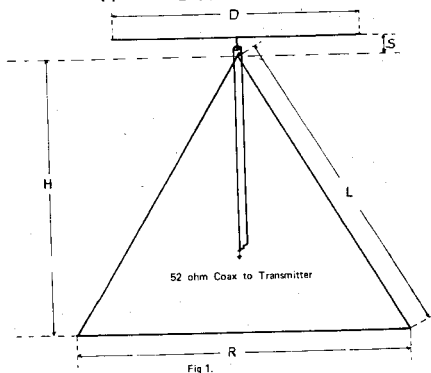
15 Metres

D = 8 feet
L = 11 feet
S = 6 inches
R = 12 feet
H = 10 feet 5 inches

10 Metres

D = 6 feet
L = 9 feet 6 inches
S = 4 inches

R = 9 feet 6 inches
H = 8 feet 3 inches



Feed impedance is determined by distance "S" and should be closely adhered to. If other feed line impedance (say 75 ohm) were to be used spacing "s" could be determined by trial and error.

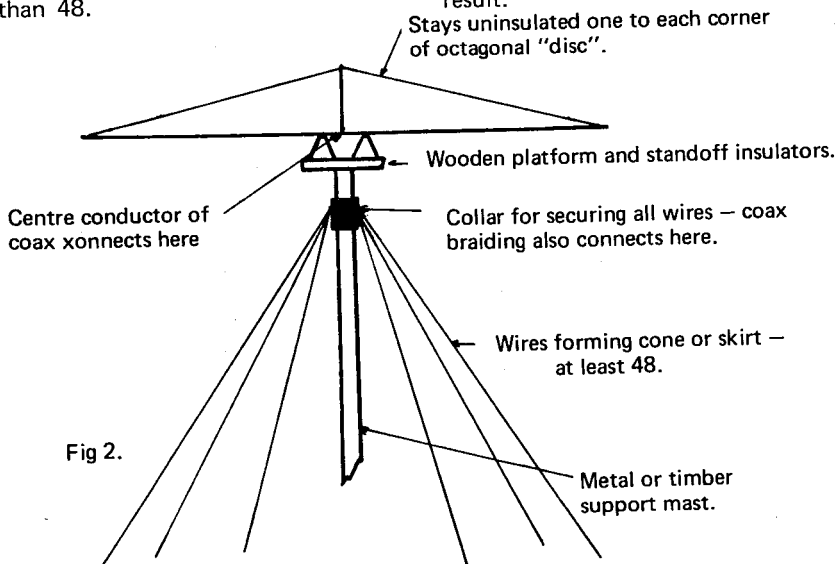
The supporting structure for the "disc" does not have to contain fantastic modulation properties because of the low feed impedance and, therefore, any hardwood suitably water proofed is perfectly adequate. A more important consideration is that the wood be of good quality and will withstand the strains introduced by the disc in a high wind, though it should be noted the wind resistance is very low with the discone.

The mast section, which may be of wood or metal, is fully supported by the multiple wires forming the cone. If a metal support is used the coax could be fed through the pipe and, therefore, automatically preventing any possible feed line radiation — the balance of the coax being buried for convenience.

The more wires that go to form the cone the better as this will help to smooth out any "kinks" in the pass-band but there should not be fewer than 48.

The centre of the disco is formed by an aluminium plate at least $\frac{1}{8}$ " thick, the eight radials are fabricated from $\frac{3}{4}$ " x $\frac{3}{4}$ " x $\frac{1}{8}$ " aluminium stock securely bolted to the centre plate.

The tips of the radials are joined by wire (uninsulated) as are the mid points of each radial. Here a word of caution — try and use aluminium wire — do not use copper as aluminium and copper are too far apart in the galvanic scale and severe corrosion will result.



The LSD

(Lightweight, Sturdy Discone)

An Omnidirectional Multiband VHF/UHF Antenna

BY PAUL H. BOCK, JR., K4MSG

THE average v.h.f. operator desiring omnidirectional coverage for equipment testing or local net operation has a variety of antenna types from which to choose. Unfortunately, the more common types, such as the ground plane, whip, coaxial vertical, halo, etc., are relatively narrowband devices; hence, the multiband operator must erect an antenna for each band on which omnidirectional coverage is desired. Despite the fact that these antennas are relatively small, and therefore do not usually create space problems, the amount of feedline required can become excessive unless the antennas are remotely switched with a suitable coaxial relay. While less expensive than multiple cables, this solution also costs money, and the end result may not justify the expense if the antennas are only put to use occasionally.

The Discone

One method of solving this problem is to erect a broadband omnidirectional radiator capable of covering several bands. The LSD (Lightweight Sturdy Discone) is such a radia-

tor. It is relatively small, lightweight, omnidirectional, vertically polarized, and has a 50-ohm feedpoint impedance. As shown in fig. 1, the discone is nothing more than a disc mounted on (and insulated from) the apex of an upright cone. The slant height of the cone, D , is equal to a free-space quarter wavelength at the lowest operating frequency; this frequency is referred to as the *design* frequency, f_0 . The base diameter is also equal to D , while the diameter of the disc is somewhat smaller, being equal to $0.7D$.

At a point approximately 20% below the design frequency, termed the *cutoff* frequency, the v.s.w.r. of a discone will rise very sharply to a high value. At frequencies above the design frequency the v.s.w.r. will generally remain below 1.6 until the upper bandwidth limit of the antenna is reached, the theoretical limit being $8f_0$. Thus, the discone appears to the feedline to be a properly terminated high-pass filter over its theoretical bandwidth. Although it is possible that the theoretical bandwidth may not be reached in practice, a bandwidth of $6f_0$ should be easily

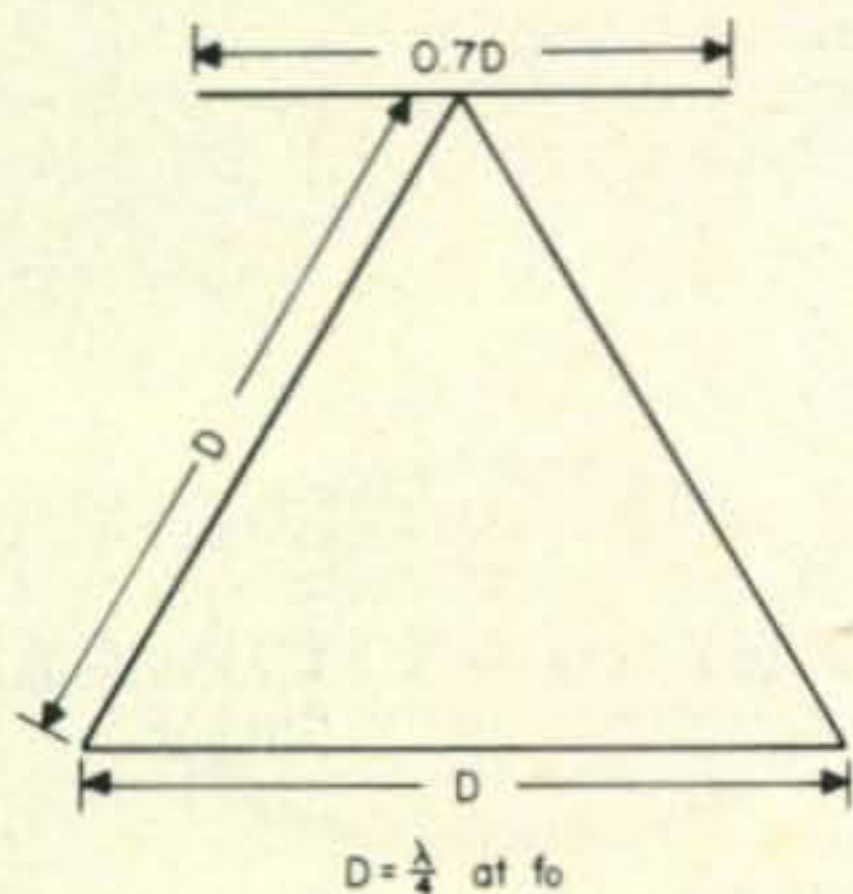


Fig. 1—Basic discone configuration.

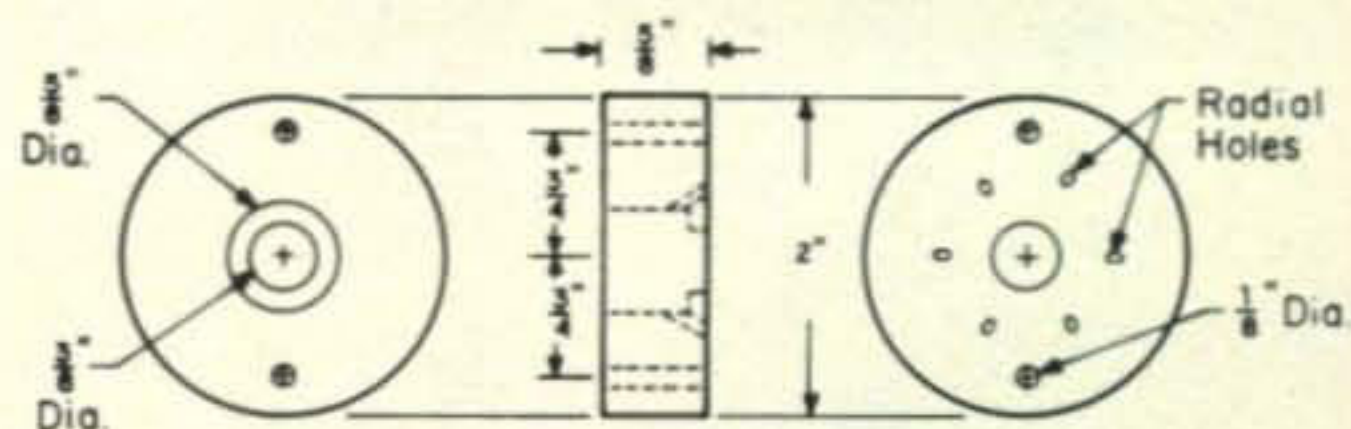


Fig. 2 — Main base mounting plate. Holes for radials are spaced 60 degrees apart on a 1" dia. circle, and tapped 6-32. Holes are drilled at an angle of 60 degrees to the surface of the plate (30 degrees to the vertical axis).

*Box 40, USNCS, FPO, N.Y., N.Y. 09544.

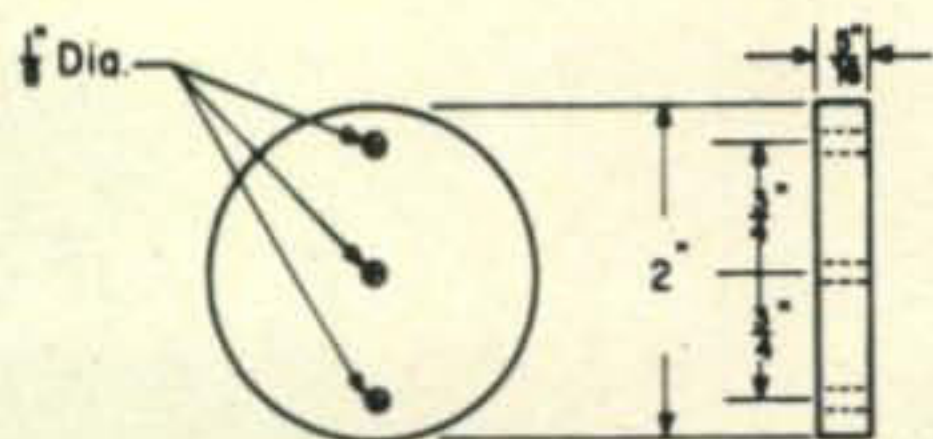


Fig. 3—Insulating disc. For low power operation most insulating materials are adequate, including even wood boiled in paraffin, at lower frequencies. At higher power and frequencies, materials such as Teflon or Nylon are recommended.

achieved using any reasonable amount of care in construction. Single discons could then be constructed for 50/144/220, 144/220/432, 220/432/1296, or 432/1296/2300.

Construction

The basic construction of the component parts is shown in fig. 2, 3, and 4, with the complete structure shown in fig. 5. The author has attempted to include sufficient information to permit duplication; in addition, there are a few basic points which must be observed if the antenna is to operate "as advertised":

(1) Both the disc and the cone can be constructed of sheet metal, or formed with a skeleton of rods. If rods are used, the minimum number for effective operation is 6, with 8 or more being preferable.

(2) The sides of the cone must form an angle of 30° with the *vertical centerline*.

(3) The apex of the cone should be located

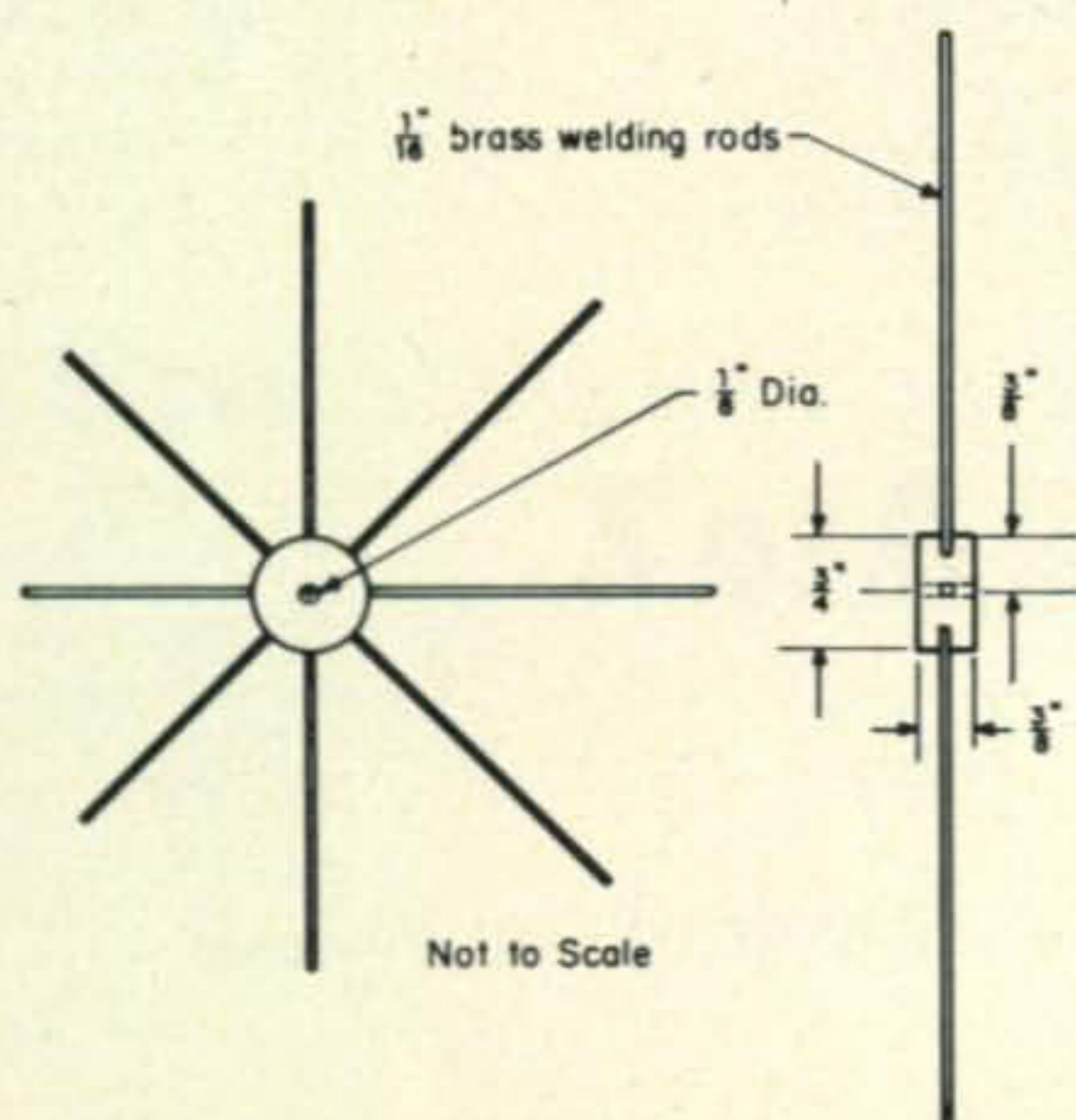


Fig. 4—Disc element. The disc hub is made from a 1/4" section of 3/4" dia. brass rod. Radials are 1/16" brass welding rod soldered to the hub. At the higher bands, a solid brass or aluminum sheet disc element would be more convenient to construct.

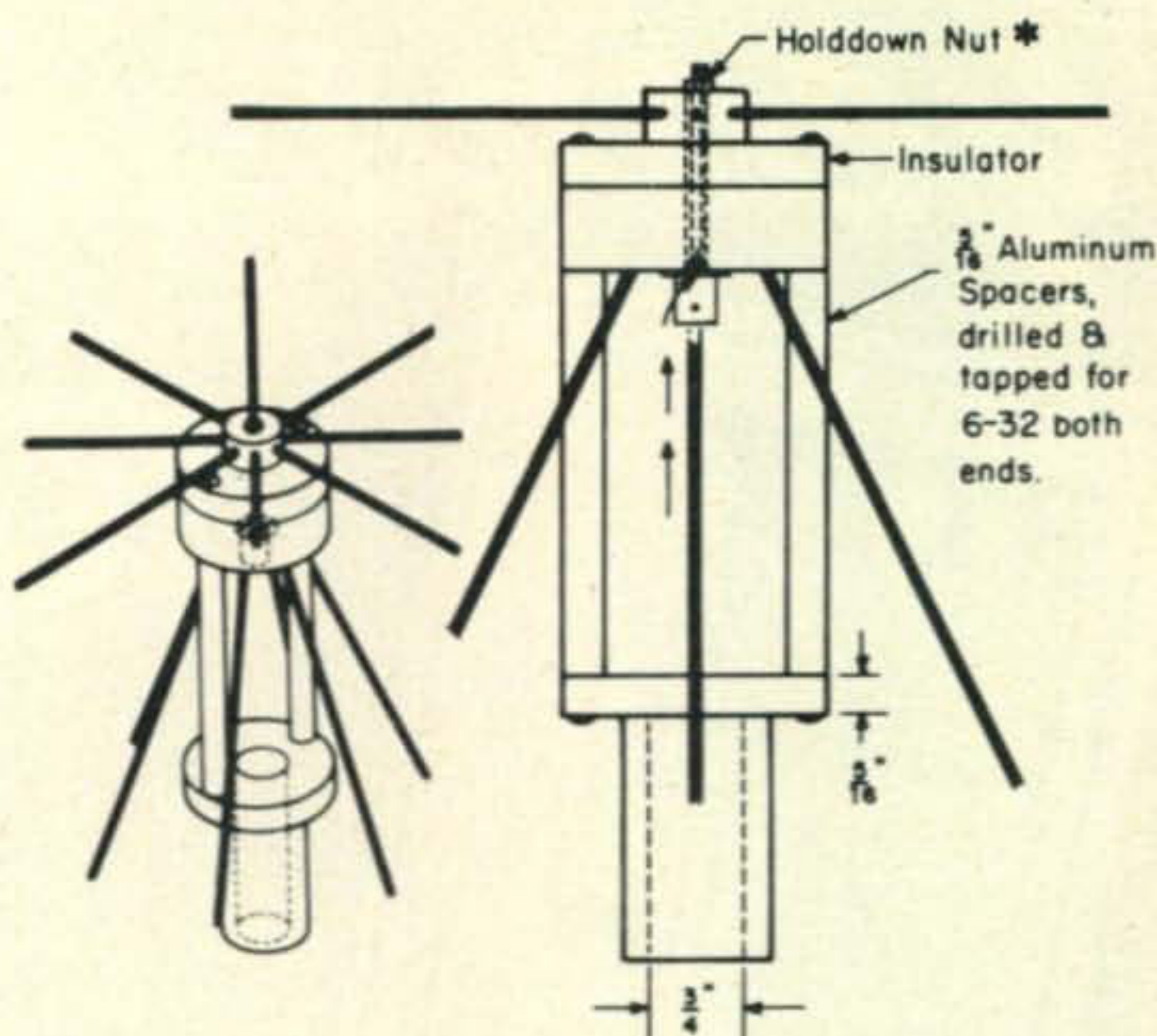


Fig. 5—The complete LSD discone assembly. An aluminum pedestal mounted on two 5/16" dia. spacers fits inside 1 1/8" aluminum tubing used as a mast. The coaxial feedline may be run inside the mast. The holddown nut fastening the disc element to the cone threads onto a 6-32 brass screw soldered to the center terminal of the BNC connector.

precisely at the center of the disc.

Actual construction is not too difficult. The author used a lathe to form some of the metal parts, but substitutions can be made readily and all holes drilled with a hand drill. The cone radials were made from 1/8-inch aluminum welding rod and threaded with a 6-32 die. The base holes were drilled by hand, using a carpenter's protractor to line up the drill at a 30° angle "by eye," and the holes were then tapped to accept the rods. The rods could just as easily be inserted vertically and then bent outward to the proper angle.

The author's version of the disc element consisted of 1/16-inch brass welding rod soldered radially to a quarter-inch length of 3/4" dia. brass rod, as shown in fig. 4. On the higher bands (220 and above), a solid disc cut from aluminum or brass sheet is simpler and more effective.

A type BNC connector was used in the version described, but if power levels over 100 watts are contemplated a type N connector should be substituted. In this case, the base should be a bit larger and the height of the disc adjusted to put it at the proper point. In the event that high power is used, it might be well to fill the hole around the connector with a good potting compound to make it weatherproof and prevent arc-over. The disc

[Continued on page 76]

ends of RX's and all in each other's hair. DX heard: W0AIH (several times), ZM1MQ, DJ6I?? GM3IGW/A and HS5ABD supposed to be on with elaborate antennae weren't heard. W4BRB/VP7: Oh! That big, fat 10 points for every W. It's better'n being on relief! (You sure did surprise us from getting on from the Bahamas, Gene. Reciprocal licensing between W/VP7 went into effect just a day before the contest. Gene made several hurried phone calls to VP7 officials, was given permission, hopped a plane, set up an antenna and gear and there we were with a VP7 in the contest — *ed.*). PY2BJH: Condx were horrible during the test... S9 plus 10 db noise level. Heard W0AIH, W8ANO and W9EWC. Called them but no results. Unfortunately there's only negligible activity on 160 in South America. (Congrats in getting those other PY's on, Hercilio — *ed.*). PJ2VD: It was a pleasure to take part in the contest. Think I made a better score than you did at PJ0CW. QRN wasn't like you experienced at Coral Cliff. Think I should be fully satisfied with this result but I am not ... mainly because I couldn't reach Europe in spite of the fact that I heard and called PA0PN for more than an hour, DL9KRA, OK2BOB, EI9J, lots of G's and a GD, GW and HB. Think the solution would be another antenna but the present one (inverted Vee half wave) is the best possible I can make. Anyway, the Rx, a 75A-4 which I just recently got hold of, proved to be a good one. Now making things ready for the coming ARRL c.w. Contest. OL4AMU: I send you my results of the CQ 160 Meter Contest. I please you excuse me. I send you not the summary calculation because I have not the regulations of this calculation. I am YL and I am 16 years. With sincere amateur greetings, 73! Your Nana. (Of all the Czech logs received this one was the only one to list any comment. — *ed.*). EI9J: Skip didn't move beyond W8 while I was on except for W9UCW and W5RTQ. W QRM was fierce at times. Old age creeping up meant that I slept for a considerable time while band was open to W. Worked all the countries I heard. Don't know how I missed out hearing PJ2VD. VP9GJ was missed. Worked him with his G call of G3PQA. G2DC: Finally hooked OE1KU after three previous attempts had been wrecked by QRM. G3XTT: Enjoyed the contest very much and look forward to future 160 meter WW contests. OH9NV: Sorry I couldn't get up a dipole for the contest. Just changing QTH so all ham gear was packed. DL9KRA: Thanks for another big event. Everything went smoothly — spares, tubes, tools and soldering guns spread out all over shack but not needed. Condx first morning excellent although HR2HH and PJ2VD not heard. Heard W4BRB/VP7 but no go. Missed out on OH0. Pity that QRL kept 9X5SP from coming on. (If he had been able to show up, Jan, we'd have had all continents on for the test for the first time ever — *ed.*). Big thing was working W5RTQ in Texas. No W6/7 heard. Second morning rather disappointing. Am sitting in Anchorage, Alaska (Jan is a Navigator for Lufthansa). Mailing deadline today.

LSD Discone [from page 24]

insulator should be made of Nylon or Teflon unless you plan to run very low power (50 watts or less), in which case anything can be used, even wood boiled in paraffin.

Performance

Although comprehensive gain testing was not conducted, a few measurements were made on a 220-1296 mc model using a remote signal source and a vertical dipole for comparison. Due to the very low-angle radiation characteristics of the LSD, some improve-

ment over the dipole was noted, and the degree of improvement was virtually constant for the 220 and 432 mc bands (separate dipoles were used for each band). This is indicative of the flat response a discone provides.

The low-angle radiation characteristics, wide frequency response, and ease of construction should make the discone an inexpensive and useful adjunct to any v.h.f. station. ■

Oscar News [from page 49]

on the 10-meter beacon after the second orbit, the mission was entirely satisfactory. The correct orbit was achieved, the stabilization system performed outstandingly, accurate telemetry data was received, the command system operated reliably, useful scientific data has been obtained, and perhaps most important, amateur radio has again demonstrated that it is seriously in the space age.

Future OSCAR Satellites

The door is still wide open for the next satellite in the OSCAR series, which will be called A-O-B until launch, and OSCAR 6 once it is successfully in orbit.

AMSAT is giving serious consideration to a single satellite containing both an f.m. channelized repeater and a linear repeater. Plans call for the f.m. repeater to use a group of uplink channels near 146 mc and a group of downlink channels in the vicinity of 432 mc. The linear amplifier would use an uplink band near 432 mc and a downlink band just below 146 mc.

The satellite would also contain telemetry transmitters operating in the 144 and 432 mc bands.

British, German and Australian radio amateurs are also giving serious thought to various versions of what may become future OSCAR satellites.

In the meantime, AMSAT emphasizes that new ideas are still being considered for OSCAR 6, and prospective participants are encouraged to submit technical proposals for consideration directly to AMSAT, P.O. Box 27, Washington, D.C. 20044. ■

Drake SPR-4 [from page 29]

dial may be indexed for calibration by slipping the skirt at the knob.

[54] **HF SUPERSTRUCTURE DISCONE ANTENNA**

[72] Inventor: **Richard L. Goodbody**, San Diego, Calif.
[73] Assignee: **The United States of America** as represented by the Secretary of the Navy
[22] Filed: **March 29, 1971**
[21] Appl. No.: **128,787**

[52] U.S. Cl. **343/710, 343/846**
[51] Int. Cl. **H01q 1/34**
[58] Field of Search **343/709, 710, 773, 846, 908**

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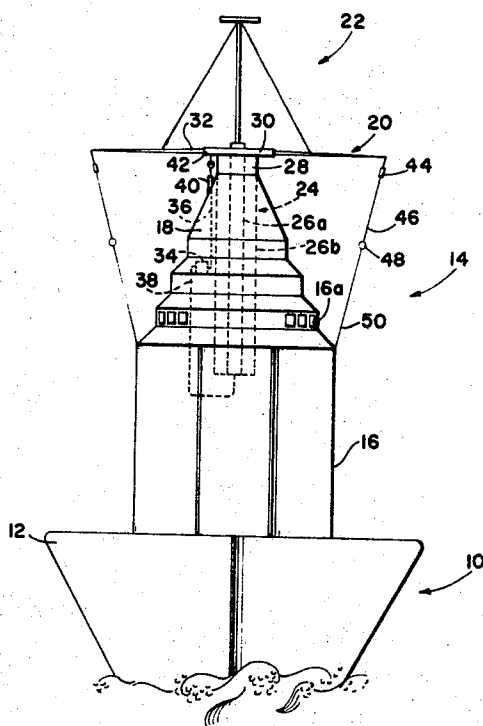
3,189,906 6/1965 Kulik et al. **343/710**

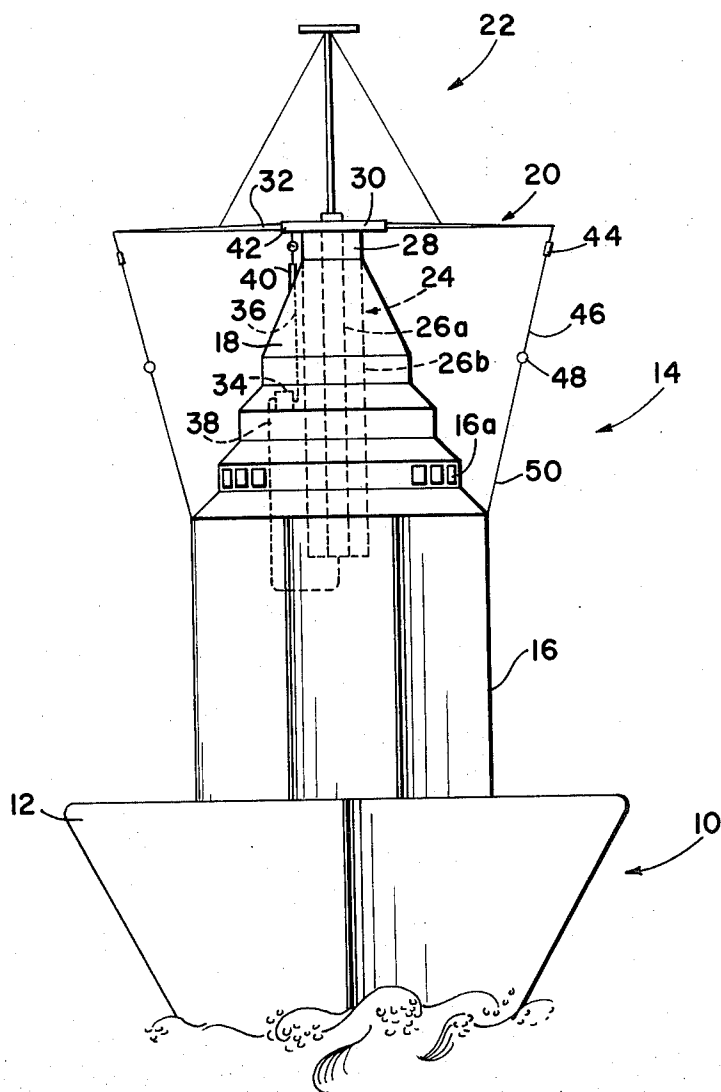
Primary Examiner—Eli Lieberman
Attorney—R. S. Sciascia, George J. Rubens and J. W. McLaren

[57] **ABSTRACT**

A superstructure discone HF antenna comprising a vertically oriented ship's superstructure and a discone antenna connected to and rigidly supported and mounted upon the top thereof to form a unitary radiating structure. By using a self-supporting superstructure as an integral component of the antenna, the number of possible HF parasitic radiators is reduced and limited topside space available on naval ships is more efficiently utilized.

4 Claims, 1 Drawing Figure





INVENTOR
RICHARD L. GOODBODY

BY

George J. Ruben
ATTORNEYS

AN HF SUPERSTRUCTURE DISCONE ANTENNA

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

Modern sophisticated naval ships include increasing numbers of electronic equipments and mechanical structures which must be located on the deck of ships. As more and more equipment and structures are required the availability of topside space necessarily becomes critical, consequently it has become necessary to design combined function equipment and to utilize topside existing structures to perform required electronic functions. In this respect, superstructures, masts, and towers on ships have been used to mount various HF radiators thereupon. The resulting environment of major parasitic radiators, however, has resulted in unacceptable radiation pattern control on most ships. Consequently it is an object of the present invention to disclose the concept for using a self-supporting superstructure on a ship as an integral component of a unitary HF antenna which can be used in a limited space environment on a ship's deck.

SUMMARY OF THE INVENTION

A unitary, self-supporting superstructure discone HF antenna is disclosed. The antenna comprises a vertically oriented superstructure having a selectively predetermined geometrical configuration upon which is mounted a discone antenna. The discone antenna which is electrically connected to the superstructure comprises a conically shaped component, a horizontally disposed disc, and a shunting stub consisting of two concentric hollow cylinders having a selectively predetermined length and a diameter ratio with respect to each other to thereby provide a shunt reactance which will allow the antenna to be matched to, for example, a 3:1 VSWR over approximately a 2 to 5.6 MHz frequency range. The superstructure can comprise any of several superstructures typically found on naval ships whereby the antenna disclosed herein can be used to advantage on ship decks where space requirements are critical. Other HF radiators can be mounted on or around the surface of the superstructure as has been done in the prior art.

OBJECTS OF THE INVENTION

It is the primary object of the present invention to provide a broadband HF antenna which includes a ship superstructure as an integral component thereof.

It is another object of the present invention to provide a superstructure discone antenna which can be used effectively in a limited space environment on a naval ship deck.

It is another object of the present invention to provide a superstructure discone antenna having improved radiation pattern characteristics achieved by reducing the number of mechanical structures acting as major parasitic radiators in the HF range.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The FIGURE is a simplified front-view of a naval ship having mounted upon the deck thereof broadband HF antenna embodying the present inventive concept.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The FIGURE is a simplified front-view of a naval ship 10 having mounted upon the deck 12 thereof broadband HF antenna 14 embodying the present inventive concept. The HF

antenna 14 essentially comprises a superstructure 16 of the type normally found on naval ships. The superstructure, which has a conductive surface, can have any of several geometrical configurations; in the preferred embodiment, an octagonal shaped superstructure 16 is shown. Electrically and mechanically connected to and rigidly mounted upon the top of the superstructure 16 is a discone antenna 18 which includes a disc 20, as is well known to those skilled in the art. In the FIGURE, a conventional conical antenna 22 having a trussed mast is shown mounted upon the superstructure discone antenna 14 to achieve a dual band HF capability. In the FIGURE, the water level comprises the preferred ground plane.

It should be appreciated that the entire volume of the superstructure 16 can be utilized as access, equipment, living, or operating space. For example, superstructure 16 includes a plurality of bridges 16a having bridge windows 16b. The bridges 16a can be utilized by the ship's personnel to perform their required daily functions.

The upper structure 18 is connected to the lower structure by means of an impedance matching shunting stub 24 which comprises two concentric hollow cylinders 26a and 26b. The shunting stub has an electrically predetermined length, and the ratio of the diameters of the cylinders 26a and 26b is likewise a selectively predetermined value whereby the characteristic impedance of the shunt stub which appears in parallel across the superstructure antenna can be made equal to a value which, for example, will allow a series capacitor to match the antenna 14 to a 3:1 VSWR over a 2 to 5.6 MHz range. Likewise the conical angle θ of the conical section 18 of the discone antenna is critical in that it is used to determine the characteristic impedance of the entire antenna structure 14. The combined impedance effect of the superstructure 16 and the shunt stub 24 determines the impedance "seen" at the termination 40.

The upper portion of the shunting stub 28 located between the conical section 18 and the disc 20 comprises an insulator portion 28. Mounted symmetrically on the top of insulator 28 is a support platform 30 from which a plurality of radials 32 which comprise the disc 20 radiate in a symmetrical manner. In the preferred embodiment sixteen radials are utilized.

Sending apparatus 34 are shown located in a bridge 16a. The sending apparatus can comprise transmitter or receiver means having coaxial cables 36 and 38. The cable 36 is shown connected between the sending apparatus 34 and a coaxial termination 40, which is used to feed the discone antenna at the energy feedpoint 42. Cable 38 is used when a conical antenna 22 as shown is used to achieve a dual band capability. In this instance, cable 38 would be routed through the center of the shunting stub 24 up to the energy feedpoint of the conical antenna 22 (not shown).

Each of the 16 radials 32 of the disc 20 are terminated in a 50-ohm resistor 44 from which a conductor wire 46 is connected to an insulator 48. Guy wires 50 or rope of a non-conductive material are connected between each insulator 48 and the structure 16 to thereby support and maintain the wires 46 in a selectively predetermined configuration.

At the lower portion of the shunting stub 24, the inner and the outer cylinders 26a and 26b, respectively, are both electrically and mechanically connected to the superstructure 16 which, as previously mentioned, comprises a conductive surface, as does the conical section 18. At the upper portion of the shunting stub, the inner cylinder 26a is electrically and mechanically connected to the disc 20 and the outer cylinder 26b is mechanically, but not electrically, connected to the disc by the insulator 28 which is also mechanically connected to the cone 18, the outer cylinder 26b is electrically and mechanically connected to the cone 18.

The outer cylinder 26b may be electrically and mechanically connected to any part of the superstructure 16 by means of, for example, a bulkhead within the superstructure to thereby rigidly support and maintain the stub 24 in a predetermined position.

Experimentation has shown that by means of conventional exiting multi-couplers and multi-coupler techniques, the composite structure 14, including the conical antenna 22 can provide simultaneous operation of up to as many as 16 transmitters and forty receivers, for example, in the 2 to 15 MHz band. Furthermore the single structure antenna 14 can be installed on a variety of ships wherein the superstructure can also perform those functions normally required of ships' superstructures. This antenna thus comprises a major contribution to ship space utilization in terms of efficient use of topside space and especially in the reduction of parasitic radiators. Consequently it can be appreciated that an entire large superstructure can be made into a broadband HF antenna on which other radiators such as those for radar functions can be mounted in a concentric or co-linear manner on the surface of the superstructure (not shown). This capability to support these other radiators thereby eliminates much of the antenna blockage which occurs on existing ships due to the presence of platforms and equipments.

The conducting surfaces of the superstructure can be formed of electrically conducting solid sheets, welded pipe, or wires spaced at suitable intervals depending on mechanical requirements and upon requirements for weather-tight internal spaces.

The desired characteristic impedance match as previously mentioned is obtained by selectively predetermining the dimensions of the shunt stub and the conical angle θ . The diameter of the disc and the overall height of the structure are determined in part by the desired low-frequency response.

The superstructure 16 itself can comprise either a rectangular, pyramidal, or cylindrical, or conical geometrical configuration; however the cylindrical conical shape has been found to be optimum for overall symmetry. The conical shape is shown distorted in the figure to accommodate other functions such as windows for the bridges. Furthermore equipment such as conformal radar arrays and platforms can be easily installed external to the conducting surfaces, although this capability is limited by the tolerance of discontinuities resulting in impedance perturbation.

The conical antenna 22 located above the disc is not a critical part of the discone superstructure concept, however it is shown in the figure to show how easily the present invention could be modified to provide a dual band HF capability within a unitary structure and without requiring more of the critical

space topside of the ship. Thus it can be appreciated that a new and novel combined function HF antenna for use on topside ship environments where space is critical and including as an integral component thereof, a ship's superstructure has been disclosed.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. An HF antenna for use in limited space environments on naval ship decks comprising:

a superstructure having a selectively predetermined configuration and an electrically conductive surface;

a discone antenna rigidly mounted and supported upon the top of said superstructure and being electrically connected to said superstructure by means of a shunt stub extending symmetrically through said discone antenna and a selectively predetermined length of said superstructure, said discone antenna having an electrically conductive surface also.

2. The apparatus of claim 1 wherein said discone antenna comprises:

a conical portion mounted atop of said superstructure; an insulator portion at the top thereof, and a disc connected at the top of said insulator in a symmetrical manner with respect to said insulator, said insulator being symmetrically disposed about said shunt stub.

3. The apparatus of claim 1 wherein said shunt stub comprises:

two hollow concentric cylinders symmetrically disposed within each other and about the center of said superstructure.

4. A dual-band HF antenna for use on decks of naval ships comprising:

a superstructure having a predetermined geometrical configuration;

a discone antenna mounted and rigidly connected to said superstructure by means of a shunt stub extending therebetween; and

a conical antenna having a trussed mast mounted atop said discone antenna.

* * * * *

THE HF DISCONE ANTENNA

A Frequency Independent Antenna
For Vertical Polarization

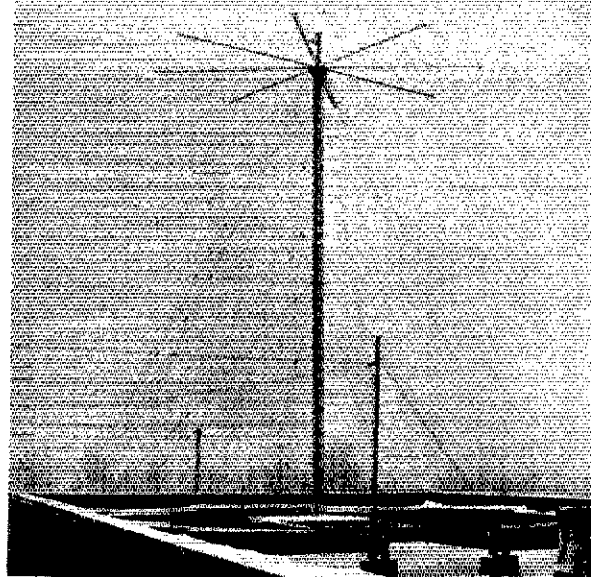
BY JOHN S. BELROSE,* VE2CV/VE3DRC

The discone antenna has existed for years, but little information on this radiator has appeared in amateur publications. While the array looks like a guyed 36-foot tower having a large top hat, it offers the performance of an efficient vertical monopole but may be operated independently of any earth ground. It covers 40 through 10 meters without critical tuning, traps, or band switching, and provides an excellent match to 50-ohm coaxial line.

IN 1957 Victor Rumsey explained the basic requirements for frequency-independent antennas. The concept was that if the shape of the antenna could be specified entirely by angles, its performance would be independent of frequency. This is because the shape of the antenna, when expressed in wavelengths, would be the same at every frequency. The log-periodic antenna, which is the best known of this class of antennas, was devised by DuHamel and Isbell¹ in 1957. In 1959 Isbell² developed the dipole arrangement currently used. The discone antenna was developed by Kandoian³ in 1945, and is a radiator having an impedance that can be directly matched to a 50-ohm coaxial transmission line over a wide

* 3 Tadoussac Dr., Lucerne, Quebec, and Department of Communications, Communications Research Centre, P.O. Box 490, Station A, Ottawa, Canada K1N 8T5.

¹ For this and all subsequent references, see the listing at the end of this article.



frequency band. The discone also belongs to the log-periodic class of antennas.

The fact that the discone antenna does belong to the log-periodic class will be made clear below. The antenna comprises a vertical cone beneath a horizontal disk (see Fig. 1). For frequencies within the range of the antenna, the radiation is due to a resonance between the fields caused by current flow over the disk and over the surface of the cone, which is established by its flare angle. The apex of the cone, which is vertical, approaches and becomes common with the outer conductor of the coaxial feeder at its extremity. The center conductor of the coaxial feeder terminates at the center of the disk, which is perpendicular to the axis of the cone and the feeding transmission line. The discone can be thought of as an upside-down conical monopole, an antenna type that was devised much earlier.

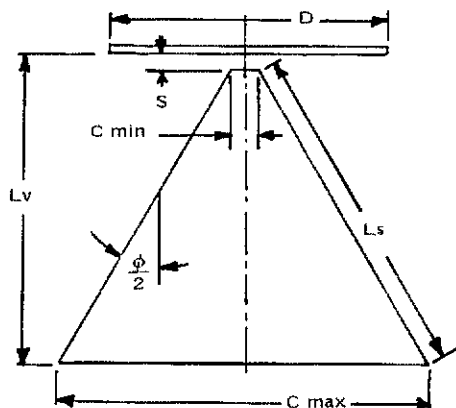


Fig. 1 — Cross-section sketch of the discone antenna. See text for definitions of terms.

The advantages of the discone are that it can be operated remote from and independent of ground. Furthermore, since the current maximum is at the top instead of at the bottom of the antenna, and since its structural configuration lends itself to mounting on a pole or on top of a building, the radiation characteristics of a practical discone antenna can approximate an *ideal* dipole antenna in free space. The change of impedance versus frequency is, however, very much less than for any ordinary dipole, even dipoles with rather small length/diameter ratios. The same is true for the radiation characteristics of the discone. The antenna exhibits good impedance characteristics over a ten-to-one frequency range and low-angle radiation with little change in the radiation pattern over a three- or four-to-one frequency range. At the high-frequency end the pattern begins to turn upward, with a resulting decrease in the radiation at low elevation angles. The discone antenna may be visualized as a radiator intermediate between a conventional dipole and a biconical horn. A biconical horn⁶ is essentially a conical dipole operated at frequencies for which the physical dimensions of the antenna become large compared with a wavelength. At the lower frequencies the antenna behaves very much as a dipole; at much higher frequencies it becomes essentially a horn radiator.

Design Considerations

Refer to the sketch of the discone radiator in Fig. 1. The following nomenclature is used:

- ϕ = cone flare angle (total)
- L_s = slant height of cone
- L_v = vertical distance from the disk to the base of the cone
- $C_{\max}$ = maximum diameter of cone
- $C_{\min}$ = minimum diameter of cone
- D = diameter of disk
- S = disk-to-cone spacing

From model studies Nail has determined the optimum parameters for discone antennas to be as follows:

$$S = 0.3 C_{\min}$$

$$D = 0.7 C_{\max}$$

and typically, for an optimum design

$$L_s/C_{\min} > 22$$

$$\phi = 60^\circ$$

The performance of the antenna is not very critical in regard to the value of flare angle, ϕ , except that there is less irregularity in the SWR versus frequency if $\phi > 50^\circ$, although $\phi > 90^\circ$ was not investigated. Since the bandwidth is inversely proportional to $C_{\min}$, that dimension must be small; for a frequency range of ten to one $L_s/C_{\min}$ should be greater than 22.

From the circuit standpoint the discone antenna behaves essentially like a high-pass filter. It has an effective cutoff frequency, f_c , below which it becomes very inefficient, causing severe standing waves on the feeding coaxial line. Above the cutoff

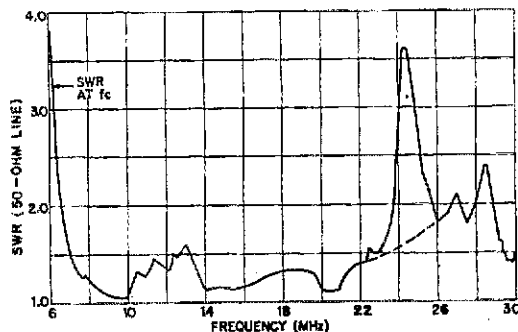


Fig. 2 — Standing-wave ratio vs. frequency for the discone antenna designed for operation on 7 MHz and above. The "spike" in the curve at approximately 24 MHz is believed to be caused by an adjacent metal structure, as explained in the text.

frequency little mismatch exists and the radiation pattern remains substantially the same over a wide range of frequencies (from some minimum frequency, $f_{\min}$, to some maximum frequency, $f_{\max}$). The slant height of the cone, L_s , is approximately equal to a quarter wavelength at the cutoff frequency, f_c , and the vertical height (or altitude) of the cone is approximately a quarter wavelength at the lowest operating frequency, $f_{\min}$.

The radiation from the discone can be viewed in this perhaps somewhat-oversimplified way. A traveling wave, excited by the antenna input between the apex of the cone and the disk, travels over the surface of the cone toward the base until it reaches a distance along the slant surface of the cone where the vertical dimension between that point and the disk is a quarter wavelength. The wave field therefore sees a resonant situation and is almost entirely radiated.

For $f_{\min} = 7.0$ MHz and a velocity factor for propagation along the surface of the cone equal to

$$0.96, \quad L_v = \frac{2834}{f_{\min}} = 405 \text{ inches.}$$

$$\text{If } \phi = 60^\circ, \text{ then } L_s = 456 \text{ inches and } f_c = \frac{2834}{L_s} = 6.22 \text{ MHz. The disk diameter is } D = 0.7$$

$$C_{\max} = 0.7 (456) = 319.2 \text{ inches, and for } C_{\min} = 13.5 \text{ inches (a practical dimension which we shall}$$

$$\text{see later), } S = 0.3 C_{\min} = 0.3 (13.5) = 4 \text{ inches.}$$

$$\text{The ratio } L_s/C_{\min} = \frac{456}{13.5} = 33.7.$$

The frequency response of a discone antenna constructed with these dimensions is shown in Fig. 2. Here we see that the SWR is 3.25 at f_c and decreases rapidly with increasing frequency, being about 1.5 at $f_{\min}$. The SWR is < 1.5 over the frequency range 7 to 23 MHz, and while this ratio

increases for frequencies > 23 MHz, the SWR, except for the irregularity for frequencies 23.5 to 25.5 MHz, is < 2.5 MHz over the frequency range 6.5 to 30 MHz. The SWR peak in the frequency range 23.5 to 25.5 MHz is thought to be due to a resonance in the metal structure of a nearby part of the building on which the discone antenna is mounted. It was mounted on a flat roof 70 feet from a penthouse which is 21.25 feet in height (including the grounded metal rail around the top). This height is a resonant half wave at 24.4 MHz.

Practical Construction

At hf the discone can be built using closely spaced wires to simulate the surface of the cone. The disk can be simulated by a structure consisting of eight spreaders with wires connected between them. It is important that a skirt wire connect the bottom ends of all slant wires simulating the cone, and another the outer ends of the spreaders which simulate the disk. These wires have the effect of increasing the effectiveness of the wire structures

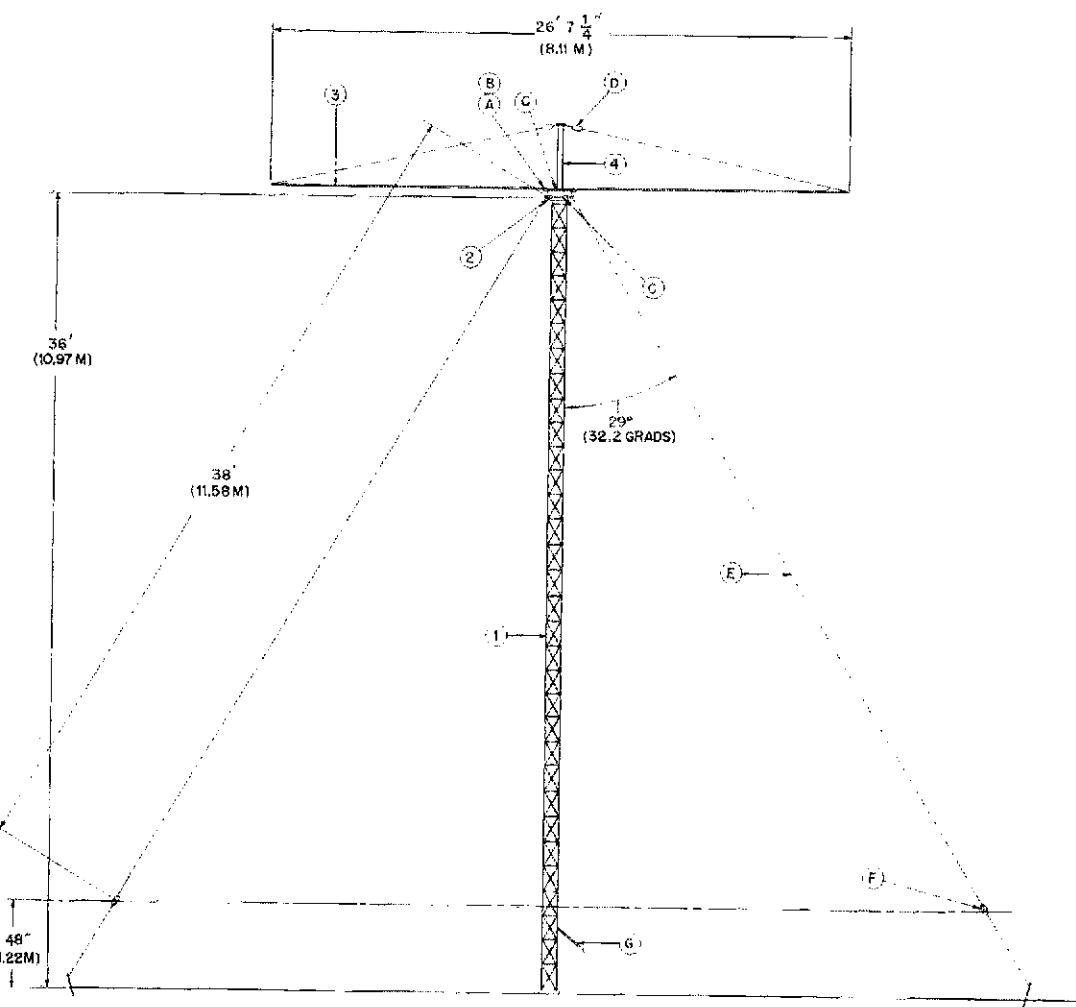


Fig. 3 — Construction details for the hf discone antenna.

- A — Hex-head screw, 1/4-20 $\times$ 2-in. long, 16 req'd.
- B — Hex nut, 1/4-20 thread, 16 req'd.
- C — Hex-head screw, 3/8-16 $\times$ 1-in. long, 8 req'd.
- D — 6-in. turnbuckle, 8 req'd.
- E — No. 12 Copperweld wire, 1400 feet req'd.
- F — Porcelain or ceramic insulators, 24 req'd.

- G — 50-ohm coaxial feed line, length as required. Line is secured to mast and connected at feed point shown in Fig. 4.
- 1 — Antenna mast with cap.
- 2 — Insulator subassembly. See Fig. 4.
- 3 — Spreader, made from 1-in. aluminum tubing, 8 req'd.
- 4 — Spreader support, 3-ft. length of steel or aluminum pipe or tubing, flange mounted.

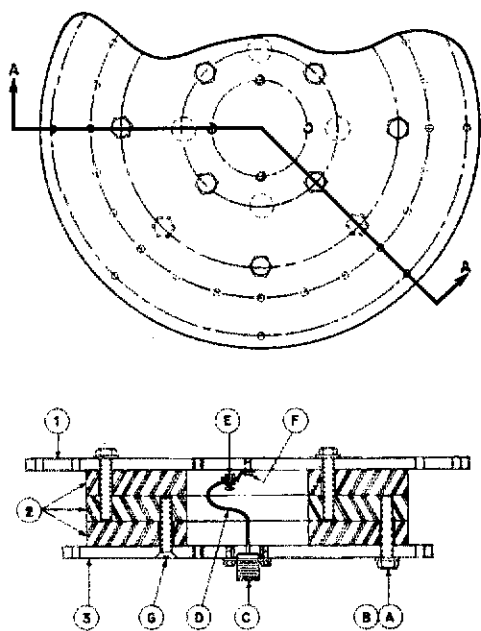


Fig. 4 — Construction details of insulator sub-assembly.

- A — Hex-head screw, 1/2-13 × 2-1/2-in. long, 12 req'd.
- B — Flat washers, 1/2-in. 12 req'd.
- C — Rf connector, as required.
- D — 6-in. length of copper wire.
- E — Wire lug, Emco 14-6 or equiv.
- F — Round-head screw, 10-32 × 3/8-in. long.
- G — Flat-head screw, 1/2-13 × 2-1/2-in. long, 4 req'd.
- 1 — Aluminum mounting plate for disk spreaders.
- 2 — Phenolic insulator rings.
- 3 — Guy mounting plate.

to a considerable extent. An antenna constructed in this way closely approximates the performance of a solid disk and a cone over the frequency range of the antenna.

The discone assembly and construction details are given in Fig. 3. The antenna is supported by an eight-inch triangular aluminum mast (item 1) which is 36 feet high. The insulator separating the disk and the cone (item 2) is detailed in Fig. 4. Basically it is two metal plates separated by an insulating section. The lower plate has a coaxial feedthrough connector mounted at its center, and the outer edge is drilled with 24 equally spaced holes, 5/32-inch diameter, on a 13.5-inch diameter circle for the guy wires that simulate the cone. The end of each wire is soldered to a spade lug that is attached by a self-tapping machine screw to the plate. This plate is bolted to the top of the mast. Eight 1-inch diameter disk spreaders (item 3) are bolted to the top plate. A short 3-foot supporting rod (item 4) is flange mounted at the center of the upper plate to hold the cables for supporting the far ends of the spreaders. The center conductor of the coaxial feed line is attached to the center of the top plate, as shown in Fig. 4.

The antenna is mounted on the flat roof of a three-story building. The height of the lower edge of the cone is 4 feet above the roof. The 24 guy wires simulating the cone are broken by 12-inch porcelain insulators (item F) at their bottom ends, and, as previously mentioned, the ends of each wire are joined by a skirt wire, as shown in the figure.

Performance

The discone antenna shown in the photograph was constructed in 1968, and it is still in use. It has survived more than one freezing-rain ice storm. The entire antenna and all supporting wires on at least one occasion were covered with 1/2-inch radial thickness of ice. A 3-element triband amateur beam covered with this thickness of ice also survived the ice storm but it was unusable; it was detuned too much by the ice sheath. The performance of the discone was unaffected by the ice. In fact at an operating frequency of about 14 MHz, paradoxically, the SWR was marginally lower when the antenna was covered with ice compared to normal. The antenna has no sharp corners or ends, and it is operated at dc ground (the cone is grounded and the disk is grounded through the input coil of the receiver). Because of this the antenna is essentially immune to precipitation static due to electrically charged rain, such as frequently falls in the Ottawa Valley during summer months. A log-periodic antenna is normally used for hf communications at the Communications Research Centre Amateur Radio Station, VE3DRC. Under conditions of precipitation static this antenna frequently builds up static-charge noise levels equal to a signal strength of S4 to S9 on a Drake R4C receiver, even though the antenna is operated at dc ground. By contrast, there is apparently no static buildup on the discone antenna. The noise levels are essentially that of the atmospheric noise intensity of the distant or nearby thunderstorm.

The antenna exhibits most of the usual characteristics of a vertical monopole. It is certainly and not surprisingly much superior in performance to the horizontal log-periodic antenna for communications over ground-wave ranges with a mobile station using a short vertical whip. The usual vertical monopole antennas have a characteristic overhead null in the radiation pattern, and for short-distance sky-wave communications a horizontal dipole is in general the best antenna. In our experience, however, communication was always possible with the discone, to distances beyond that over which the ground wave could be received, provided of course that the ionosphere would reflect a frequency of 7 MHz (the lowest frequency for which the antenna could be used). While there is certainly a null overhead, it is not a very deep one, and with a linear amplifier at the base station the mobile could always copy the base station if the base station could copy the mobile.

The antenna has been used for many hundreds of contacts on four amateur bands, 40, 20, 15 and

(Continued on page 56)

license at the entry level which would be more attractive to prospective amateurs. The main objection to the FCC-proposed Communicator is that it is a "something-for-nothing" license; it grants so many desirable privileges that few people will want to upgrade. Also, because it requires no familiarity at all with the Morse code, Communicator licensees might not be encouraged to upgrade. The League's proposed alternative, called the Basic Amateur license, provides reasonable privileges as compared with requirements for the license. A novel feature of the Basic Amateur exam is the inclusion of basic questions on the broad range of opportunities available to amateurs with higher classes of license, to ensure that new amateurs are aware of the desirability of upgrading. We feel that this approach will attract large numbers of the kind of new amateurs who will be encouraged to seek the more fertile fields of the higher grades of amateur license.

Although the FCC proposal has been promoted as one having little negative impact on present licensees, in fact the present holders of all classes of license (except Advanced and Novice) stand to lose privileges if it is enacted without change. The League is firmly opposed to further erosion of privileges already earned, including the renewability of the licenses.

Further details on the League's response to Docket 20282 will be found elsewhere in this issue, including the cover. The important fact to note here is that the position adopted by the Board was worked out on the basis of detailed reference to the membership opinion survey. A strong spirit of cooperation enabled individual members of the Board to adjust their positions and response so that the overall position taken by the Board was unanimous. We feel it is truly representative of the majority opinion of League membership. We believe that amateur radio has spoken so clearly in this matter that there can be little reason for a delay in its conclusion along the lines proposed by the League.

And when the final report and order is announced, the League is ready to proceed with strong support of this unified approach to licensing and amateur privileges. We are committed to the adoption of League programs which will encourage the revitalization and growth of the amateur radio service.

- WIRU

10 meters, as well as on a number of frequencies outside amateur bands. The performance of the antenna is difficult to assess quantitatively. Compared to a log-periodic antenna, which has a theoretical gain of 13.5 dB above isotropic (dBi), we should anticipate a change of two to three S units when switching from one antenna to the other. This is assuming that the gain of the discone is not going to be greater than 2.14 dBi (the gain of a dipole antenna) and that an S unit is equal to 5 dB of signal change. At frequencies near the low end of the range, 7 MHz, the signal change is usually greater, being 3 to 4 S units. This seems reasonable. At 7 MHz the angle of maximum radiation for the log-periodic antenna occurs at 32° above the horizon, whereas low-angle radiation from the discone is optimum at this frequency. At 14 MHz the angle of maximum radiation for the log periodic decreases to 10° above the horizon, whereas the discone radiates somewhat less efficiently at low angles. The relative gain between the two antennas is therefore a function of frequency and distance and more particularly the elevation angle of the downcoming sky wave and the relative response of the antenna at that angle.

In an article in a recent issue of *QST*, Wintzer⁷ discusses experiments with simplified wire discones. While none of the experimental arrangements utilized a sufficient number of wires to simulate a discone very well, nevertheless a reasonable performance was achieved on spot frequencies in some amateur bands. The advantages of a true discone antenna can be obtained without constructing the "unwieldy monster" that Wintzer suggests it must be, and one can certainly claim that the discone is a sensible alternative for a monopole. The 4-band broadband frequency range with low standing-wave ratio and no critical tuning of traps and inter-trap spacing should appeal to many. In the eyes of the antenna man, the discone is a beauty to behold; birds also love it as rows of them are usually seen sitting of the disk spreaders.

References

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6. Nail, "Designing Discone Antennas," *Electronics*, Vol. 26, Aug. 1953, pp. 167-169.
7. Wintzer, "Dipole Passe," *QST*, Oct., 1974, pp. 15-21.

QST

folded horizontally to form a radiator for the high-frequency band. On the lower band, the antenna acts as a top-loaded vertical antenna, while on the higher band, the flat top does the radiating, rather than the vertical portion. The vertical portion, instead, acts as a quarter-wave linear transformer, matching the 6000-ohm nominal antenna impedance to the 50-ohm impedance of the coaxial transmission line.

A radial ground system should be installed beneath the antenna, two or three quarter-wave radials for each band being recommended.

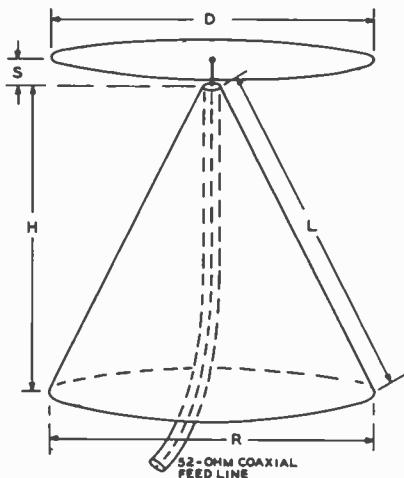
When operating on either band, the transmitter should be checked for second harmonic emission, since this antenna will effectively radiate this harmonic.

The Low-Frequency Discone Antenna—The discone antenna is widely used on the vhf bands, but until recently it has not been put to any great use on the lower-frequency

bands. Since the discone is a broadband device, it may be used on several harmonically related amateur bands. Size is the limiting factor in the use of a discone, and the 20-meter band is about the lowest practical frequency for a discone of reasonable dimensions. A discone designed for 20-meter operation may be used on 20, 15, 11, 10, and 6 meters with excellent results. It affords a good match to a 50-ohm coaxial feed system on all of these bands. A practical discone antenna is shown in figure 34, with a SWR curve for its operation over the frequency range of 13 to 55 MHz shown in figure 35. The discone antenna radiates a vertically polarized wave and has a very low angle of radiation. For vhf work the discone is constructed of sheet metal, but for low-frequency work it may be made of copper wire and aluminum angle stock. A suitable mechanical layout for a low-frequency discone is shown in figure 36. Smaller versions of this antenna may be constructed for 15, 11, 10, and 6 meters, or for 11, 10, 6, and 2 meters as shown in figure 34.

For minimum wind resistance, the top "hat" of the discone is constructed from three-quarter inch aluminum angle stock, the rods being bolted to an aluminum plate at the center of the structure. The tips of the rods are all connected together by lengths of No. 12 enameled copper wire. The cone elements are made of No. 12 copper wire and act as guy wires for the discone structure. A very rigid arrangement may be made from this design, one that will give no trouble in high winds. A 4" X 4" post can be used to support the discone structure.

The discone antenna may be fed by a length of 50-ohm coaxial cable directly



20, 15, 11, 10, 6 METERS		DIMENSIONS		11, 10, 6, 2 METERS	
D=12'	L=18'	15, 11, 10, 6 METERS		D=8'	L=9'6"
S=10'	R=18'	D=8'	L=12'	S=4'	R=9'6"
H=15'7"		S=6'	R=12'	H=8'3"	
		H=10'5"			

Figure 34

DIMENSIONS OF DISCONE ANTENNA FOR LOW-FREQUENCY CUTOFF AT 13.2 MHz, 20.1 MHz, AND 26 MHz

The Discone is a vertically polarized radiator, producing an omnidirectional pattern similar to a ground plane. Operation on several amateur bands with low SWR on the coaxial feed line is possible.

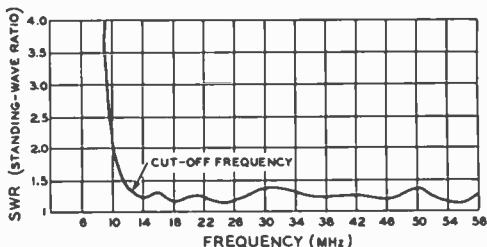


Figure 35

SWR CURVE FOR A 13.2-MHz DISCONE ANTENNA. SWR IS BELOW 1.5 TO 1 FROM 13.0 MHz TO 58 MHz

from the transmitter, with a very low SWR on all bands.

The Trap Vertical Antenna—The trap technique described in a later chapter can be employed for a three-band vertical antenna as shown in figure 37. This antenna is designed for operation on 10, 15, and 20 meters and uses a separate radial system for each band. No adjustments need be made to the antenna when changing frequency from one band to another. Substitution of a ground connection for the radials is not recommended because of the high ground loss normally encountered at these frequencies.

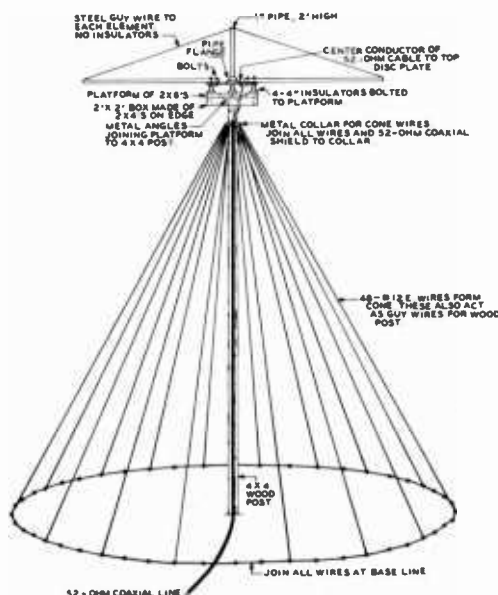
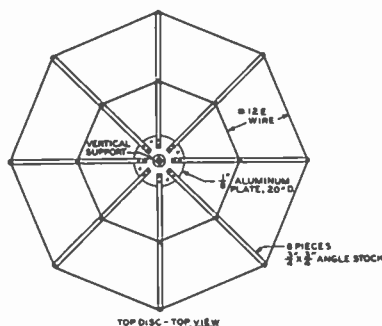


Figure 36

MECHANICAL CONSTRUCTION OF 20-METER DISCONE

Typical trap construction is discussed in the reference chapter, and the vertical radiator is built of sections of aluminum tubing, as described earlier.

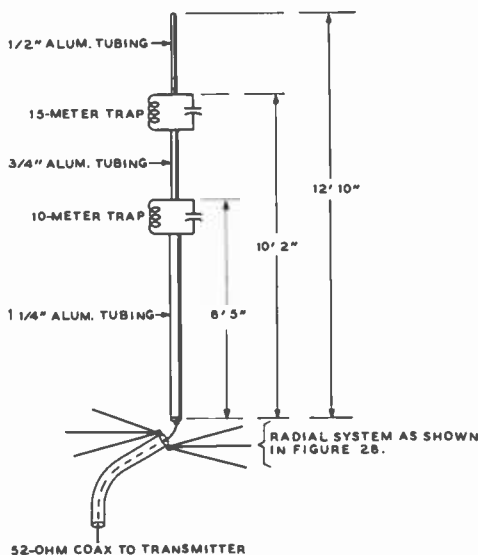


Figure 37

TRIBAND TRAP VERTICAL ANTENNA

Parallel-tuned trap assemblies are used in this vertical antenna designed for 20-, 15- and 10-meter operation. A radial ground wire set, such as described earlier in the chapter is used. Automatic trap action electrically switches antenna for proper operation on each band.

Each trap is built and grid-dipped to the proper frequency before it is placed in the radiator assembly. The 10-meter trap is self-resonant at about 27.9 MHz and the 15-meter trap is self-resonant at about 20.8 MHz. Once resonated, the traps need no further adjustment and do not enter into later adjustments made to the antenna. The complete antenna is resonated to each amateur band by placing a single-turn coil between the base of the vertical radiator and the radial connection and coupling the grid-dip oscillator to the coil. The coaxial line is removed for this test. The lower section of the vertical antenna is adjusted in length for 10-meter resonance at about 28.7 MHz, followed by adjustment of the center section for resonance at 21.2 MHz. The last adjustment is to the top section for resonance at about 14.2 MHz.

An Inexpensive Multiband VHF Antenna

A low-cost discone antenna, usable on 144, 220 and 420 MHz.

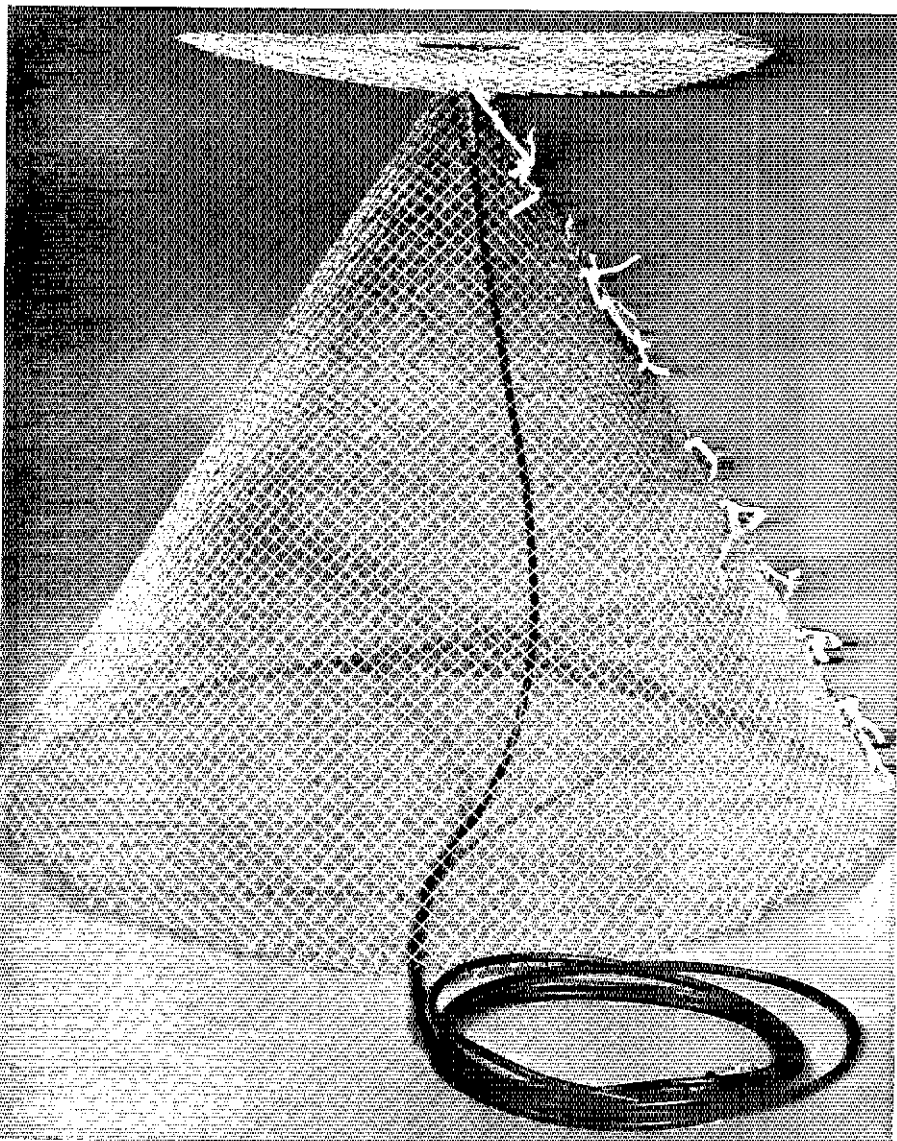
By David Geiser,* WA2ANU

When I brought my new 2-meter transceiver home, I wanted to get on the air quickly to try it out. Needing an antenna, I tried a quarter-wavelength rod. It worked, but after a few contacts I began to worry about high SWR and the effect it might have on the transmitter PA transistor. Remembering some work I'd done several years ago, I decided to build a discone, or discone antenna. While my antenna was made cheaply and simply, and intended for installation in the attic, I've given some hints to help you ruggedize your discone for outdoor mounting. If you think you might want to use a single vhf antenna on more than one band, or if you just want to try something different, you may decide to build a discone, too.

How It Works

The discone antenna functions as a wide-bandwidth, impedance-matching transformer, coupling a low-impedance transmission line to the higher impedance of free space. In the process, it radiates with a pattern similar to that of a quarter-wavelength vertical antenna above a groundplane. Waves form at the feed point (cone apex) and travel on the antenna surface to the edges of the cone and disk. The dimensions and geometry of the antenna are chosen so as to make the impedance at the edges similar to that of free space. We know that maximum energy transfer occurs when impedances are matched, so the antenna radiates. A discone antenna acts like a high-pass filter. Below some cutoff frequency, the SWR will increase rapidly. Above this frequency, the antenna SWR remains low up to a maximum of 10 times the cutoff value, depending on the design

A completed discone antenna suitable for use on the 144-, 220- and 420-MHz bands. This antenna wouldn't last long in the outdoors, but is fine for indoor use. For outside installation a more robust construction is required.



*RD 2, Box 787, Snowden Hill Rd., New Hartford, NY 13413

proportions. The unit described here shows less than 2:1 SWR from 140 to 450 MHz. At 1300 MHz, the SWR measured 5:1. Fig. 1 gives dimensional information for the antenna. The slant height and diameter of the cone are the same, about 110 percent of a quarter wavelength at the lowest operating frequency. Diameter of the disk is about 66 percent of a quarter wavelength.

Construction

At first I planned to use roofing copper to build the antenna, but quickly dropped that idea when I found that material would cost nearly \$30. I spotted a roll of hardware cloth, sometimes called "chicken wire," and decided to use that instead. It cost less than \$5 for a five-foot-long piece of two-foot-wide (1.5 × 0.6-m) material. The galvanized-steel wire that makes up the hardware cloth is spaced 1/4 inch (approximately 6 mm).

Cutting information for the discone may be ascertained from Fig. 1. A felt-tip marking pen is useful for drawing a pattern on the hardware cloth. Forming the cone may require some help. Leather-palmed gloves will protect your hands from the sharp ends of the wire. While my wife held the cone in position, I used bread-wrapper ties to hold the edges together. To make sure it stayed in place, I soldered the seam in a few locations. This was only for mechanical reasons — current flows down the cone, not around it, so electrical continuity isn't required. I found it easier to use the bread-wrapper ties if I formed them into the shape of a J, pushed the bent end through from the outside, then pulled it back out so that the loop formed around the wire. After the seam is soldered, the ties should be removed.

A 1 × 3-inch (25 × 76-mm) piece of sheet copper is supported by the SO-239 connector, and is soldered to the disk. The connector is soldered to the cone with its threaded end pointed down. The disk is supported about 1/2 inch (12 mm)

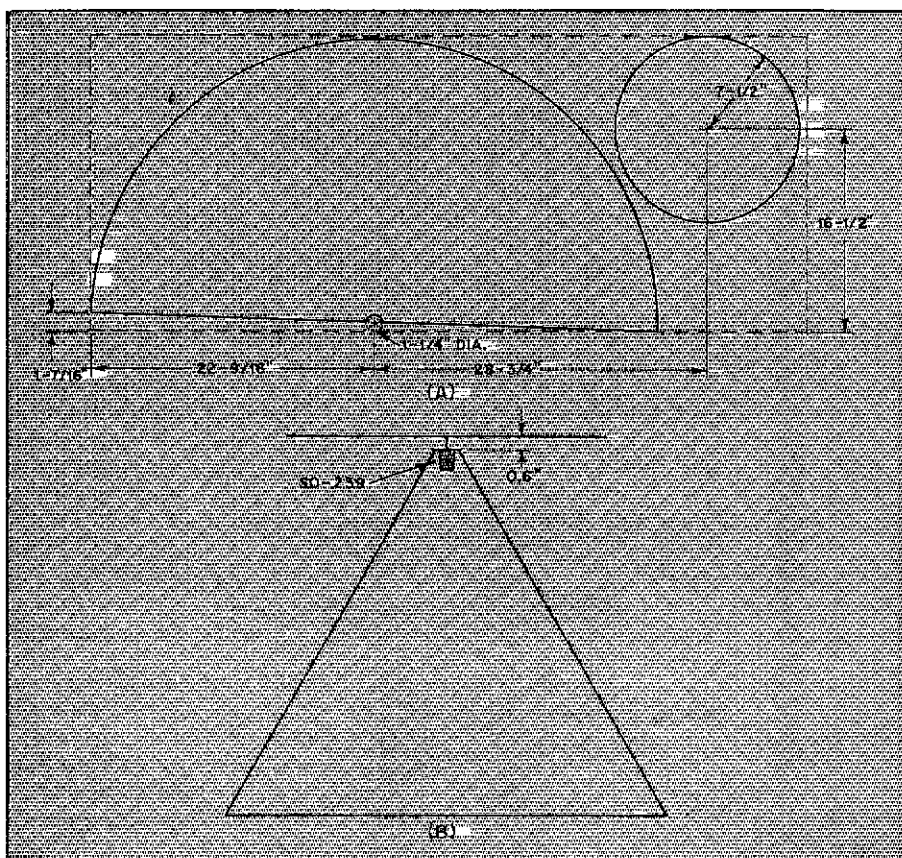


Fig. 1 — At A, cutting dimensions for the 140- to 450-MHz discone. At B, placement of the disk above the cone. Dimensions given may be scaled for other frequencies. Inches × 25.4 = mm.

above the cone.

It Works!

Naturally, as soon as I'd finished building the discone I placed it on a table, hooked up the rig and tried it out. From my rural location I could key three repeaters (it helps to live on a hill). The next day I took the antenna to work and measured its SWR in the lab. At 146 MHz it measured 1.6:1, rising to only 2:1 at 440 MHz. That night I took the antenna home and installed it in my attic. Now that it's up higher and above the aluminum siding,

it works very well. The lower edge of the cone is at the same potential all the way around, allowing the antenna to be mounted on a metal surface, although this will change the radiation pattern somewhat. A support mast that extends into the cone will have little effect on the antenna performance. Lower frequency discones may be built using a number of individual wires to make the cone and disk. The disk may be approximated with metal rods if desired. If necessary, thin, nonconductive insulators may be used to support the disk.

Strays

QST congratulates . . .

□ Phil Goetz, N6ZZ (ex-W6DQX), who has been promoted to methods and procedures manager of the Transamerica Insurance Group, Los Angeles.

OOTC PRESIDENT

□ Ray Meyers, W6MLZ, former Southwestern Division director, assumed duties as president of the Old Old-Timers Club recently, as Col. Fred Elser,

KH6CZ, resigned to pursue a doctoral degree at the University of Hawaii at Manoa.

I would like to get in touch with . . .

□ judges who are radio amateurs, especially other federal judges. J. Foy Guin, Jr., W4RLS, 354 Federal Courthouse, Birmingham, AL 35203.

SOCAL FAST SCAN

□ Southern California amateurs who are interested in uhf ATV may obtain information from the Southern California ATV Club, c/o John Ruckert, WB6ZPN, Secretary, 953 S. Beacon Ave., Los

Angeles, CA 90015, or call the club station, WA6EVQ, on 146.43 MHz.

ROBERT E. FOX, WA6TXI

□ Among those involved in the September 25 midair collision over San Diego was the PSA copilot, Robert E. Fox, WA6TXI. Licensed as a General since 1973, he had lived in nearby La Mesa.

KA6-TO-KA6 TRANSPACIFIC

□ KA6AKF/California and KA6DX/Okinawa report what they believe to be the first KA6-to-KA6 QSO across the Pacific.

DISCONE-CAGE ANTENNA

The discone-cage antenna is actually two antennas combined into one structure, each antenna having a separate feedpoint (ref A1). The highband antenna is of the discone type, utilizing an array of radial elements in a horizontal plane at the top of the cage as the disc and the upper section of the cage as the cone. The antenna is fed at the gap between the disc and the apex of the cone. The midband antenna consists of the entire cage section. The lower ends of the wires which form the cage are terminated on a collector ring which is insulated from the grounded supporting structure and used as the feedpoint.

Feedpoint impedance-matching networks are required for both sections. A shorted coaxial stub is built into the upper section of the supporting mast for matching the upper-band discone antennas to 50-ohm coax. It is occasionally necessary to add a series capacitor in the feedline, depending on antenna configuration details and the influence of antenna siting parameters. The matching network for the cage section is located in a deck-mounted enclosure at the feedpoint.

The discone-cage antenna must be located in a clear area. Adjacent structure will alter its radiation pattern characteristics and feedpoint impedances. One of the most successful locations has been on the bow of ships other than carriers. To avoid interference with anchor-handling requirements, the discage has been successfully installed on a bridge structure erected over the anchor machinery area. In other installations the antenna has been mounted on a pedestal, approximately 7 feet high, to reduce the electrical shock hazard to personnel.

Several versions of the hf discone-cage antenna have been developed and built by various shipyards. The electric near fields were calculated for the discone-cage antenna of figure A4. The antenna is mounted on a 7-foot pedestal. The calculated electric near fields of this antenna are given in figures B13 and B14. The frequencies are 3, 5, 7, 9, 11, and 13 MHz. The radiated power is 1 kW. Again, all the figures are graphs of the peak electric field in volts/meter as a function of horizontal distance, x , away from the antenna. Figure B13 presents the electric near fields for a vertical height of 1 meter off the extended ground plane, figure B14 the electric near fields for a 2-meter vertical height.

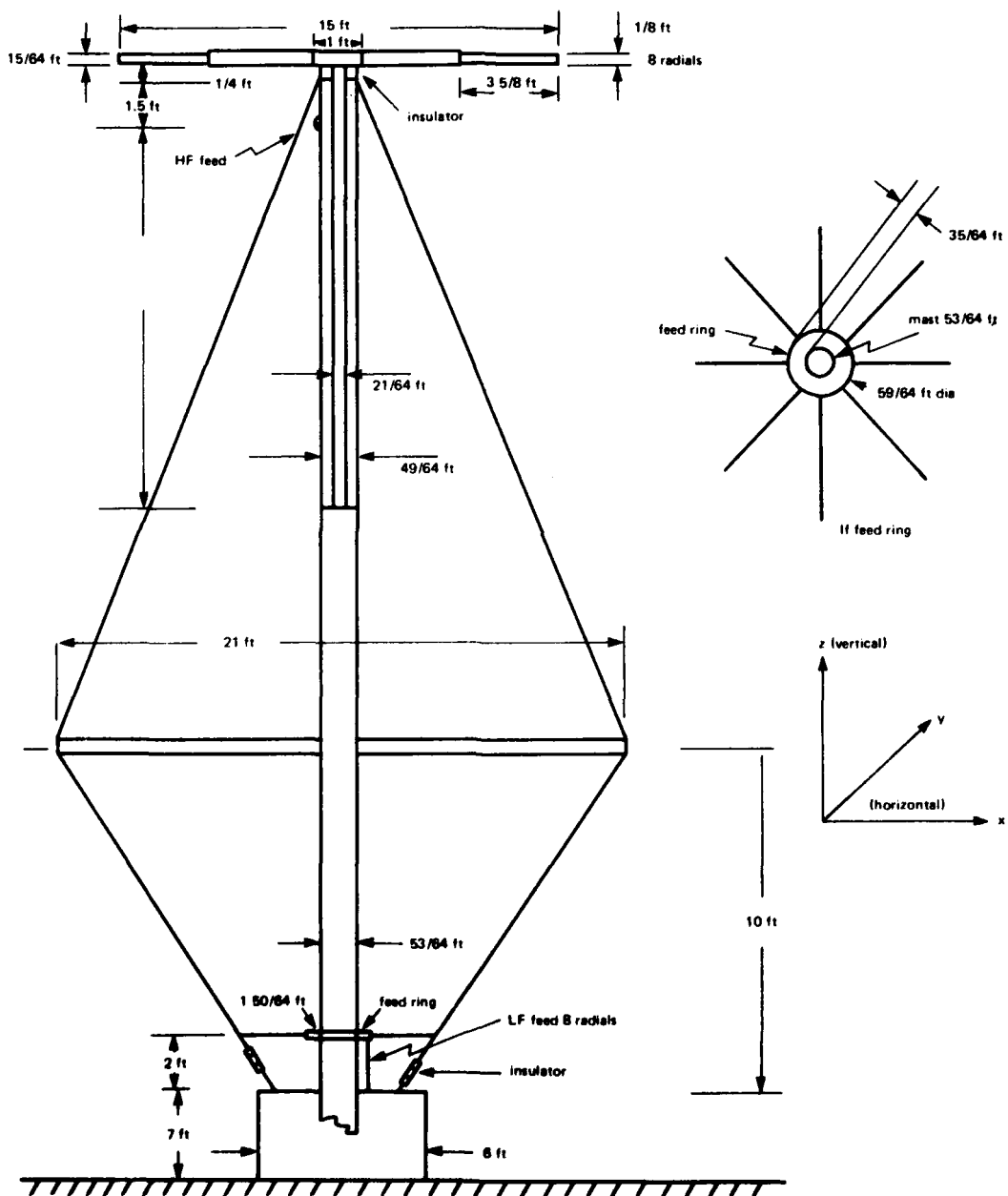


Figure A4. Discone-cage antenna.

Oil up the lathe and get set to build another of K3WBH's mechanical marvels. Most of it can be built with simple tools you probably have and the results will certainly be worth the effort.

A Discone Antenna For 10 And 6 Meters And Lo-Band Public Service Monitoring

BY T.E. WHITE*, K3WBH

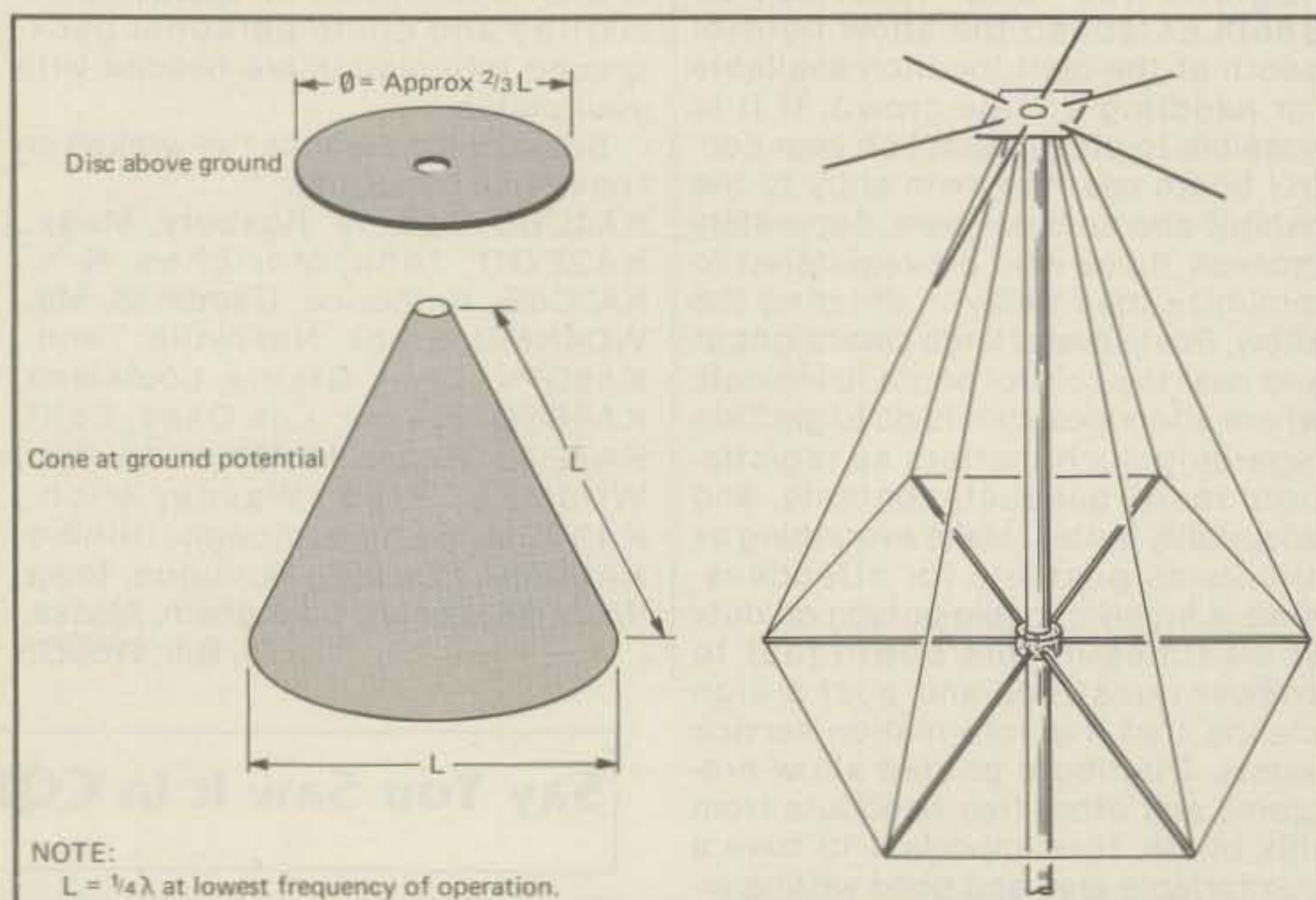


Fig. 1 - The basic discone antenna and its evolution.

“What the heck is that?” will echo through the neighborhood when you proudly erect this dashing, dramatic discone.

Amateurs wishing to get on 10 and 6 and chase sunspot and sporadic E DX will get very good results with this low-angle vertical antenna, also FB for working 6 meter repeaters. A single feed line switched at the shack between rigs serves both bands.

For those not familiar with the discone, it is a very broad-band

radiator, working from its low cutoff frequency up to theoretically infinite limits. By making the cutoff (the point where the skirt is less than $1/4 \lambda$) 28 MHz, we can work 10 and 6 (and even 2) and, if we want to, listen in on public safety, transportation and other services in the 30-50 MHz band.

The discone evolves from a solid disc atop a hollow cone (fig. 1). It is not necessary to maintain plane surfaces, however. We can simulate them by rods, wires, tubes, netting, etc., and make a much lighter antenna in the bargain. The radials are bridged between tips to make a web or “hem.”

This may be dispensed with at higher frequencies but is helpful at low v.h.f. in decoupling skirt from disc.

Feeding is a breeze. 52 ohm coax attaches directly with no matching devices needed. The antenna is largely independent of ground reflections, works well at most any height, and is far superior to the stick-and-radials variety of vertical antenna. In fact, no other single-unit vertical equals it for low radiation/reception angle. You'd need many dipoles piled up vertically to come close, and then you wouldn't be frequency-independent.

While the discone requires some lathe work or access to a metal shop, construction is straightforward. Ex-

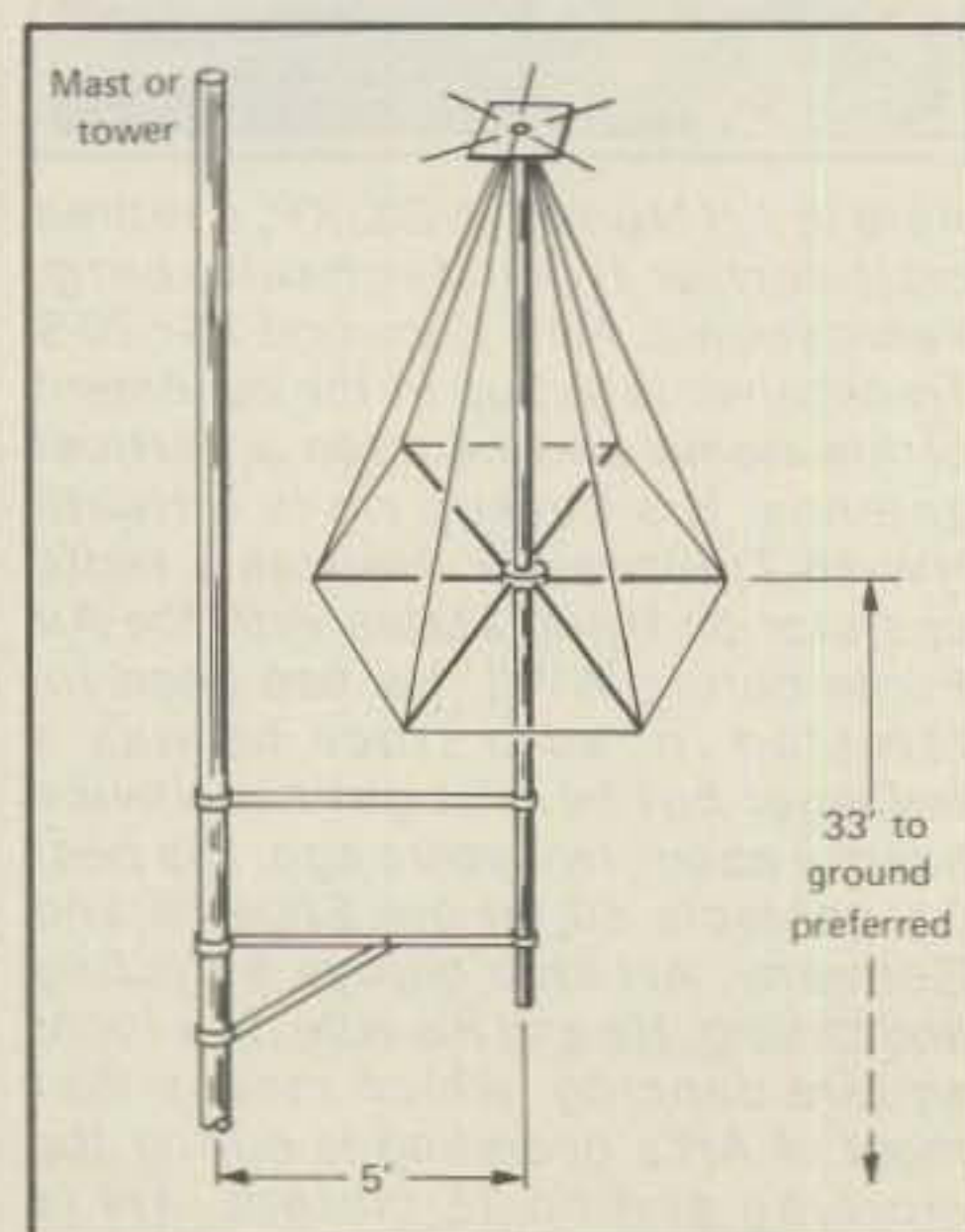


Fig. 2- A side mounted discone antenna.

*36 Lake Ave., Fair Haven, N.J. 07701

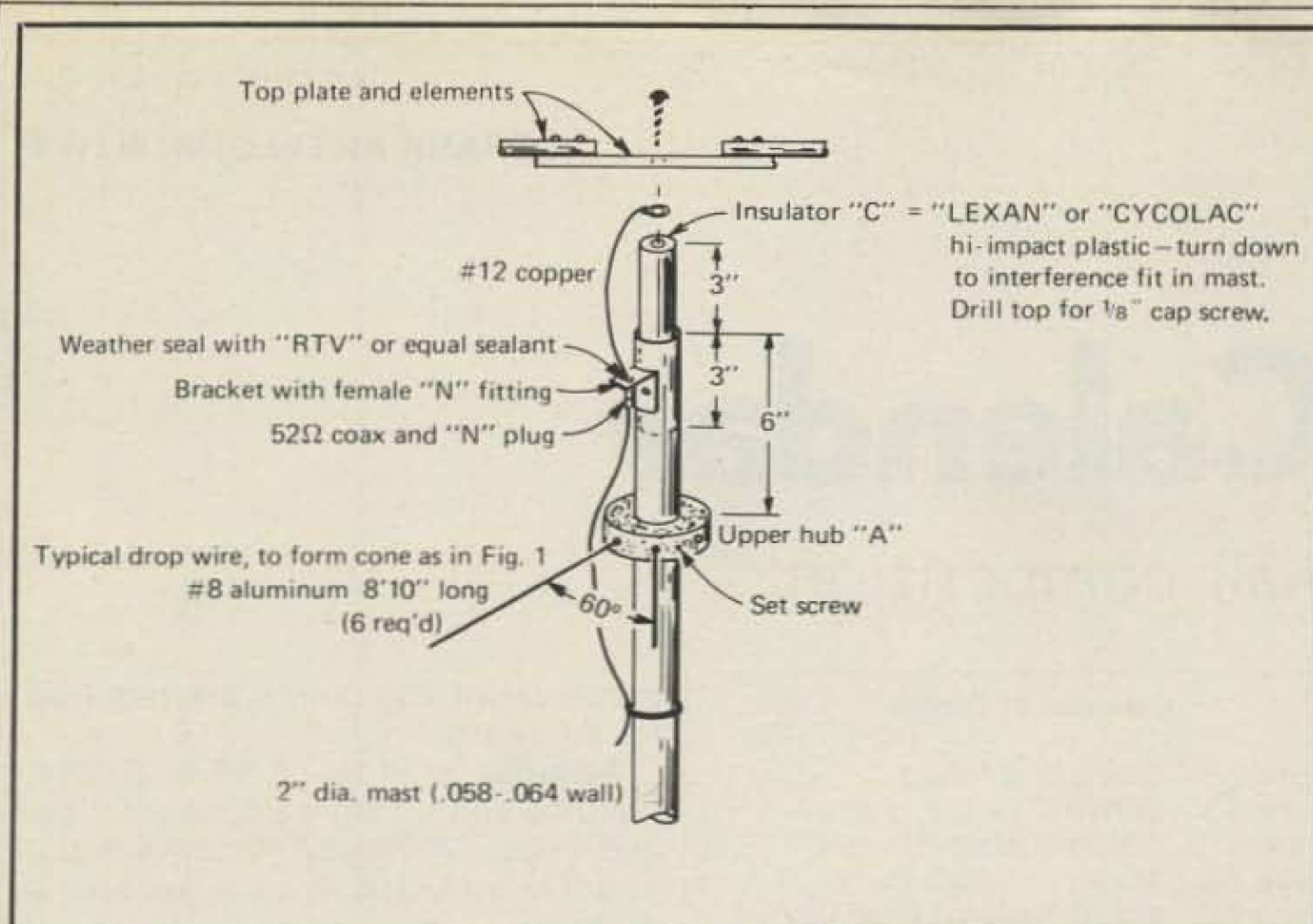


Fig. 3 - The assembly of the top junction.

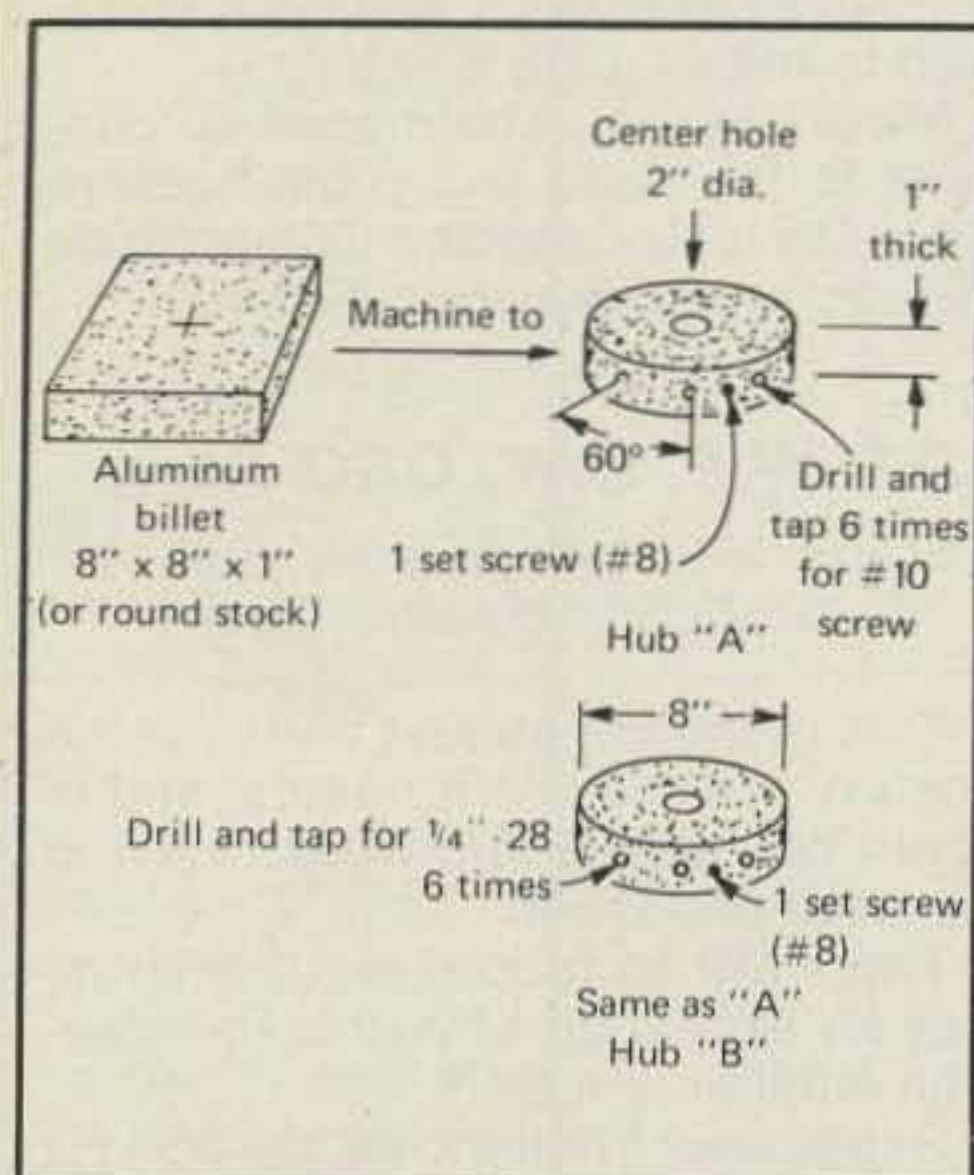


Fig. 4 - Machining details for hubs A and B.

cept for the hubs, only hand labor is required. It can be mast-top mounted or hung out the side of a tower (fig. 2).

The top assembly is "live" at all times with respect to lightning, especially if mast-top mounted. When not in use, the coax should be disconnected from the rig and plugged into a receptacle whose inner conductor lug is shorted directly to ground.

The secret of 10 and 6 meter DX is not Texas kilowatts or 50 foot booms. It is low wave angle. Those sporadic E ionized clouds are often far from your QTH. To bounce off them with maximum effect requires the lowest "angle of approach" you can possibly get. Spend a few hours making this "torn umbrella" and forget the 15dB yagis. You'll be glad you did. [E]

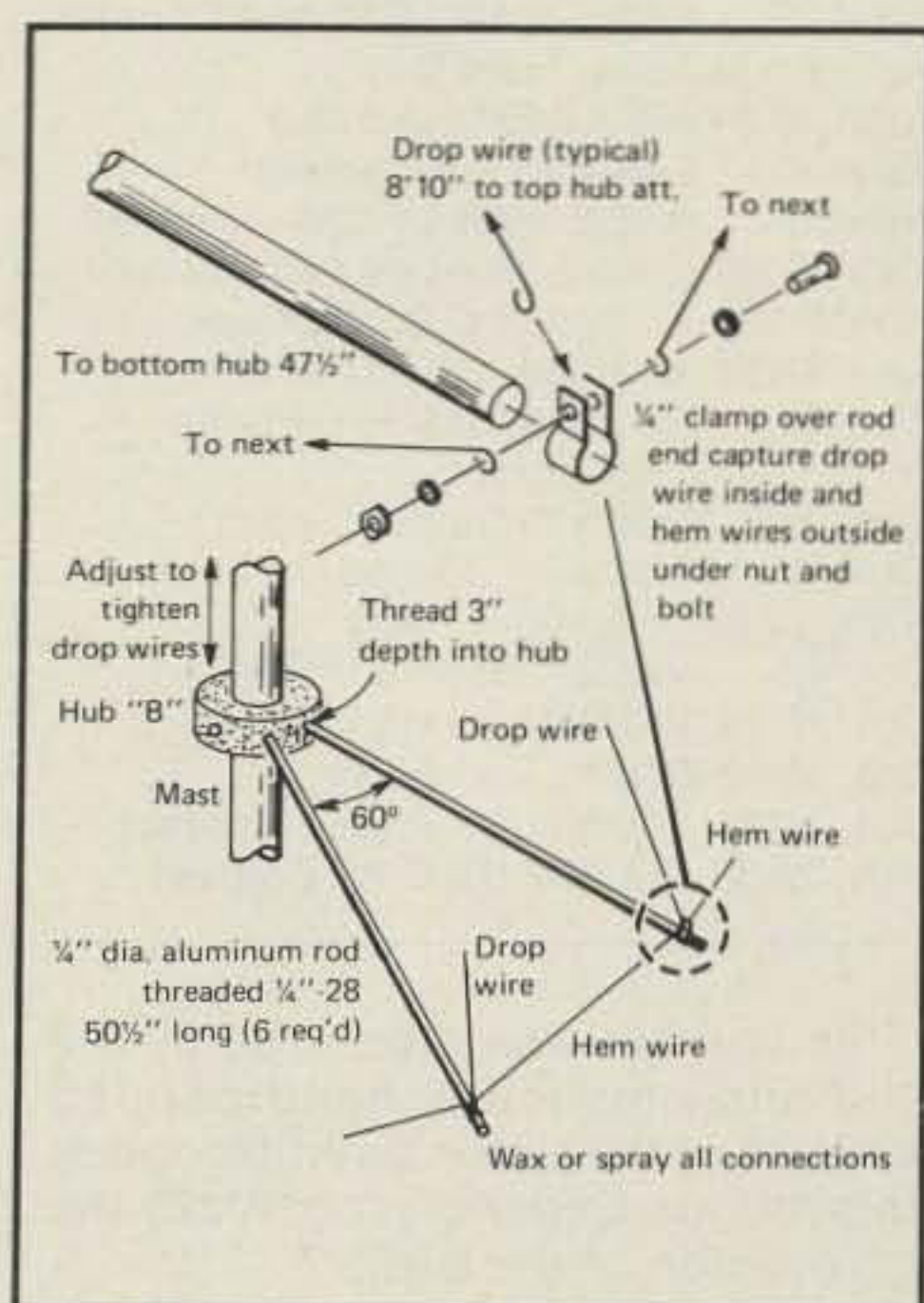


Fig. 5 - Assembly of the lower portion.

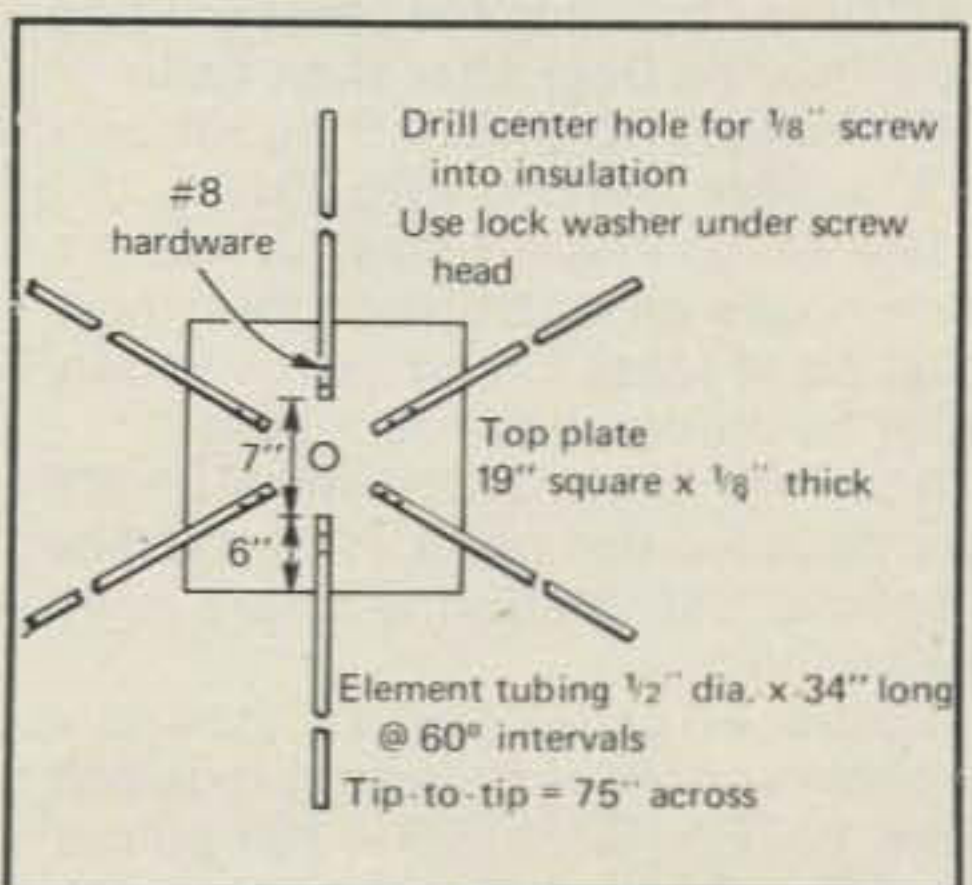


Fig. 6 - The top plate and element assembly.

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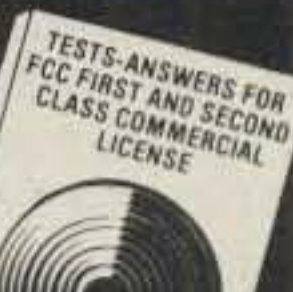
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A Discone Just For Fun

Fun to design, build and use.

by L. Scott Hall KAØDAQ

"What's wrong? Couldn't you make the last antenna work?" My wife always says this when I'm working on a new antenna. Putting up and taking down antennas is what I do in amateur radio. Anyway, that was a year ago last fall. It was a discone.

Does a discone sound high-tech? That's not how I made it, but it works.

First thing, when I decided on this project, I looked up what other people had to say about discones. Two references were found: *The ARRL Antenna Book* and *Home-Brew HF/VHF Handbook* by William Hood. I found Mr Hood's book to be particularly useful.

Defining the Project

A discone is a vertically polarized antenna with a disc (a capacitive hat $0.68 \times$ the base width) on top and a cone a quarter wavelength at lowest frequency, from the vertex (the point at the top) to the edge of the base (an equilateral triangle from the side). The base is a quarter wave in diameter (see Figure 1). Mr Hood states that the disc should be spaced 6" from the cone vertex at 14 MHz (no formula was given). A discone should operate over a large frequency range. My plan was to use it on 10 and 15 meters. I took these numbers and plugged them into my pocket computer to run them a few times.

```
10: Input F
20: B=492/(2*F) or B=150/(2*F)
    for metric
30: D=0.68*B
40: Print B,D
50: Go to 10
```

Nothing fancy here—just the bare bones. Where F equals the lowest usable frequency, B equals base diameter and D equals the disc diameter.

The final design used 20.5 MHz as the lowest frequency because the SWR is supposed to rise rapidly at the lowest usable frequency. 20.5 MHz is a little below the 15 meter band, but I wanted the SWR to be low all the way to the bottom of the band. And it made the math easy. My final dimensions were 8'2" for the disc, 12' for the cone, and 4" for the spacing (I guessed for the spacing).

Before beginning I had to determine the number of radials to use. My reference book said one radial every $1/50$ of a wave. That

would be 38 or 40 radials. I didn't believe this number, so I did some experimenting.

Modeling

I decided to build a model. The commercial FM band (88-108 MHz) often uses dual polarization. A discone should work on the vertical portion. A tin can about 4" in diameter was used for the vertex, with a hole in the remaining end for the coax, and 12 small holes punched around the open end to attach the cone radials. The coax is fed through the open end, then through the coax hole, with the braid pulled back 2" and soldered to the can. The 2" of insulated center conductor is fed through a 1" thick, 8" wide wooden disk. Two short screws hold the can to the disk. Any insulation on the coax above the wood

cut in the radials ends and crimped for a good mechanical connection.

After the top hat was up, I strung only two cone radials (stranded wire) from the can to start with (a stiff wire base loop was used to hold the radials in place). A small-diameter stick held to the vertex can by one screw was all the support needed. Hooking this up to an FM receiver with a signal strength meter, I was surprised to find it bidirectional. Adding a third was better. After six radials, gain was not noticeable on my equipment. I guess $1/50$ th of a wave for radial spacing meant without a base wire.

Since I planned on using a base wire to tie all the radials together, I decided on 15 radials per wave, or 12 for this antenna. I chose 12 radials for a better SWR on 10 and for lots of capture area.

Mounting Problems

The cone and disc for the full-size discone are very much like the test model's: a circle of plywood holding six elements, with the far ends shorted together to form the disc and 12 stranded copper wires hanging from a tin can and attached at the bottom to the base loop. The real problem is the supporting hardware. Holding up a tiny model is a lot easier than a disc over 8' across. The parts for this antenna sat around a long time before I finally came up with something I thought would work.

I always knew I'd use a 1-1/2" steel mast for supporting the antenna, but how could I attach it without any possibility of shorting out the cone and disc, yet still holding the disc 4" above the cone?

Mounting Solutions

The mount (spacers) consists of three pieces of 2x4 and a 5" circle of plywood (the 2x4s are 15", 8" and 3-1/2" long). First the 15" and 8" 2x4's were glued together (I used a hot glue gun) with their centers aligned (see Figure 3). A 1/2" hole drilled down the center gave me room to feed the coax through.

I heated up the glue gun again and stuck these two, the large end, to the bottom of the disc. I made sure that the hole in the disc and the spacers were lined up right. The can already had 12 holes punched in it for the radials and the coax hole in the remaining end. After slipping the coax through the hole I stripped off 5" of insulation, then bent



Photo A. The discone.

is stripped off. I poked a hole in the center of the tin can lid (the one removed to empty the can) and soldered it to the center conductor on top of the disk. The disc radials (six broken TV antenna elements cut to 11") were attached with screws, and the outside ends joined with a copper wire through a slit

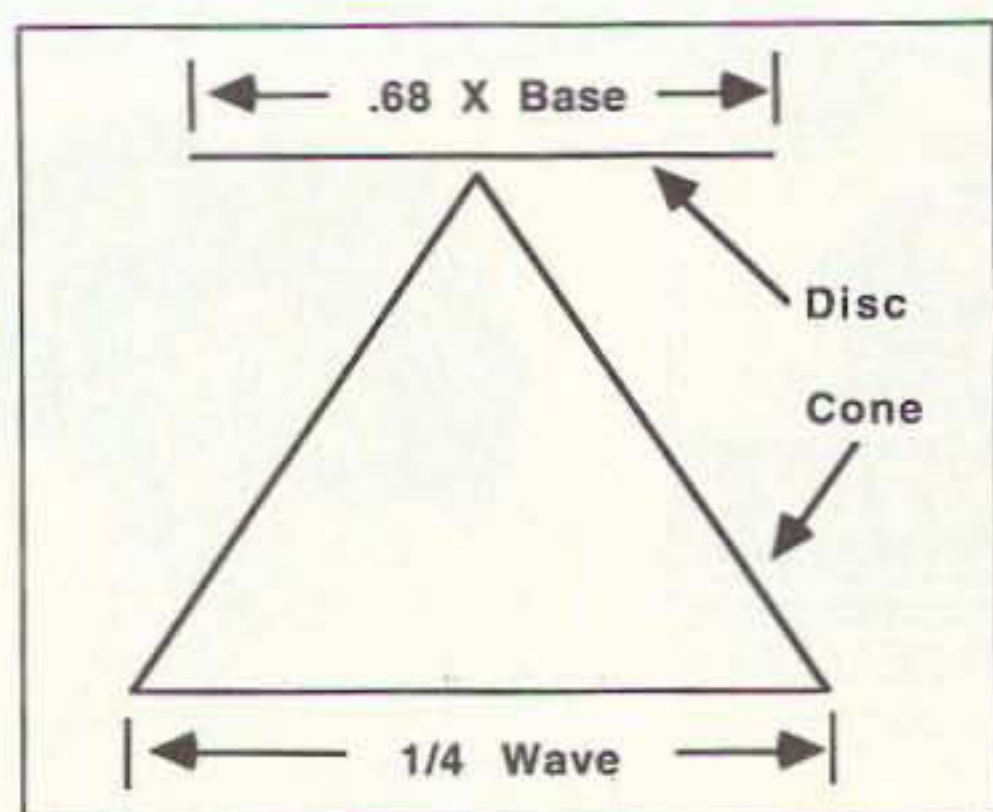


Figure 1. Discone measurements.

back and soldered the shield to the top of the can.

This is when I should have soldered the radials on to the can, but no, I did it the hard way. I slipped the center conductor through the center hole and, using more hot glue, pressed the can into place. I drilled a coax hole in the center of the 5" plywood circle and a mast hole in the 2x4 before gluing them together (see Figure 3). The plywood fit snugly into the can. And the mast, with the coax slipped through it, fit snugly into the 2x4 mast hole. This 2x4 collar keeps the mast from shifting. The plywood circle supports the weight of the whole antenna on the top of the mast.

Remember how on Field Day everyone puts up lightweight masts with guy lines? Now turn that picture upside down; that's how I hold the disc level. A guy line ring is mounted 3' down from the disc and four evenly-spaced ropes are tied from the edge of the 2' plywood disc to the guy ring (see Figure 2). This does a great job of holding

the disc steady.

A stiff wire simply wasn't going to hold 12 radials in place as on the model. I used a stranded wire for the base loop and six 6' sticks (1" x 1"). Two parallel holes were drilled in each stick, one through each end. While soldering the radials to the base loop, I slipped a stick on after every two radials. When all the radials and sticks were in place and the base wire was soldered together, I brought all six ends together around the mast and threaded a rope through the end holes. Then, taking up the slack, I pulled them all tight to the mast, like the spokes of a wheel, and tied them off level with the base loop.

Wrap Up

When I turned on the receiver the first

time I knew I had a winner, it worked great. Signals were coming in from everywhere. This antenna worked just like the books said it would: low SWR over a broad bandwidth, and a low angle of radiation for DX. At least this is true for the lowest 10 MHz I played with. Theory states the this discone should have a working bandwidth from 20.5 MHz to 205 MHz, but without VHF equipment I was unable to prove it.

My discone was fun to design, build and use. It had good receive and transmit qualities. I liked it, but it had some problems. Foremost, it pulls in signals from everywhere, not a good quality on crowded bands or in contests. With these qualities it might work well for a net control station, but not a good choice for your only antenna.

73

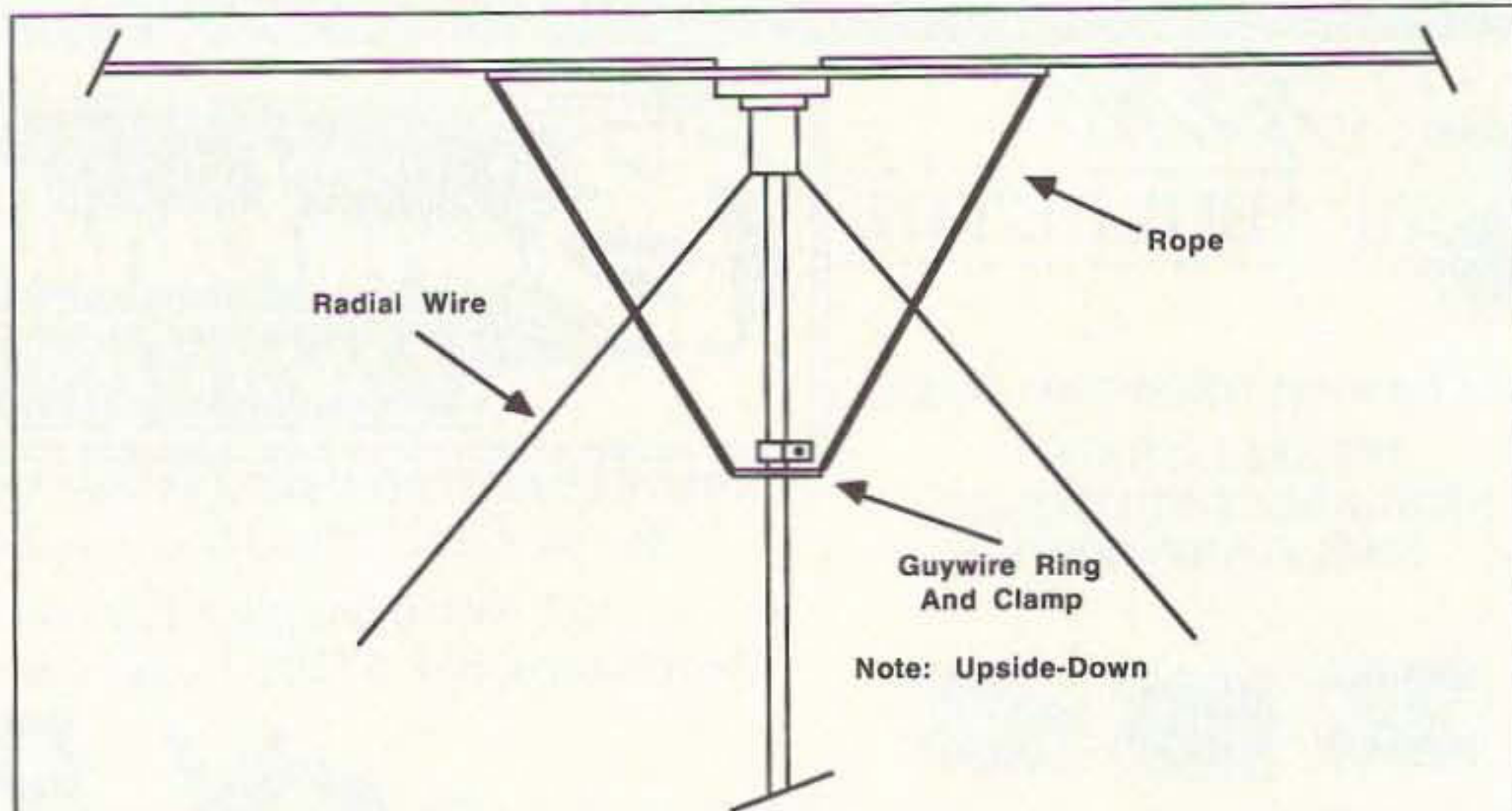


Figure 2. Guy ring mounting detail.

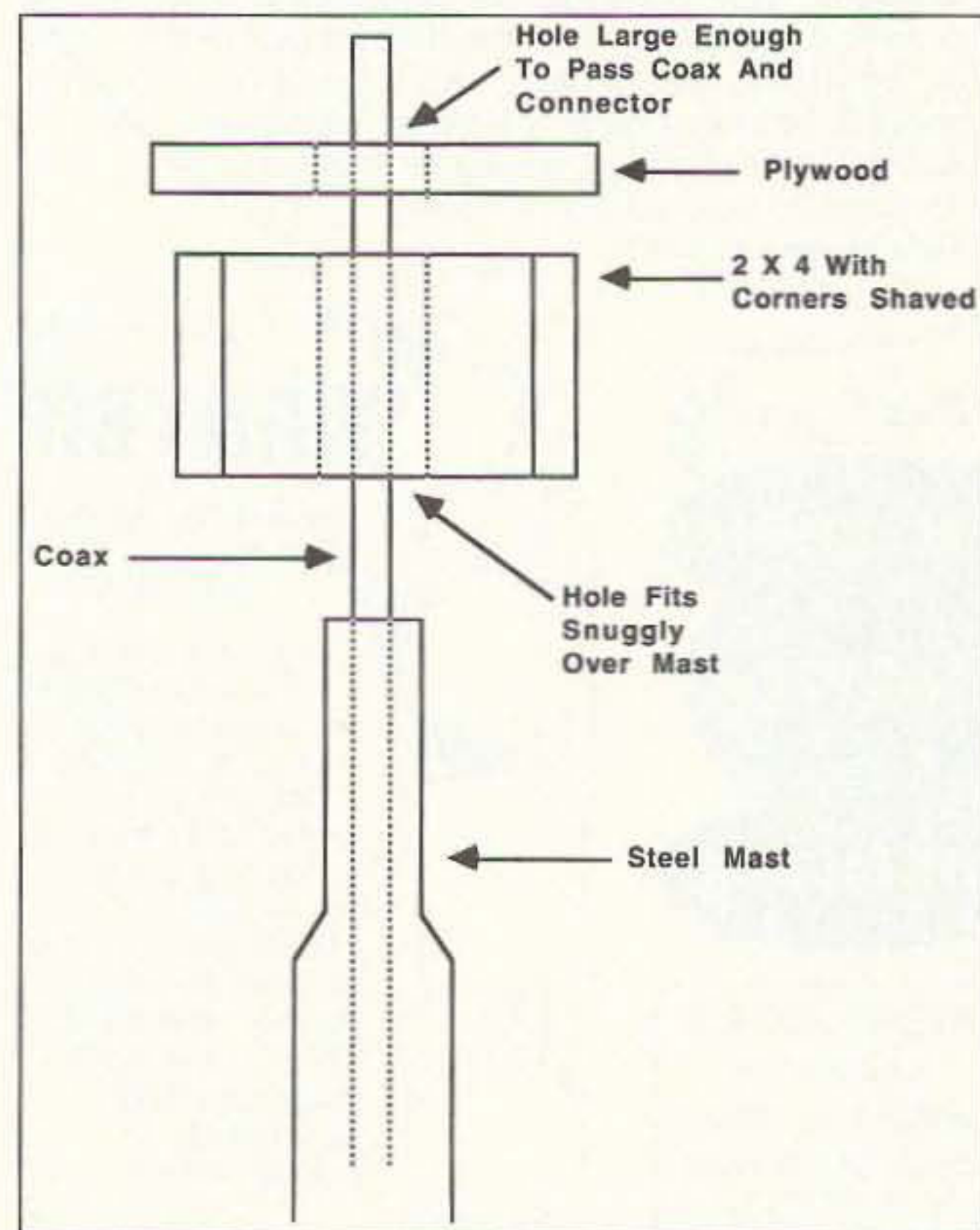


Figure 3. The 2 x 4 wood collar—plywood circle mounting detail.

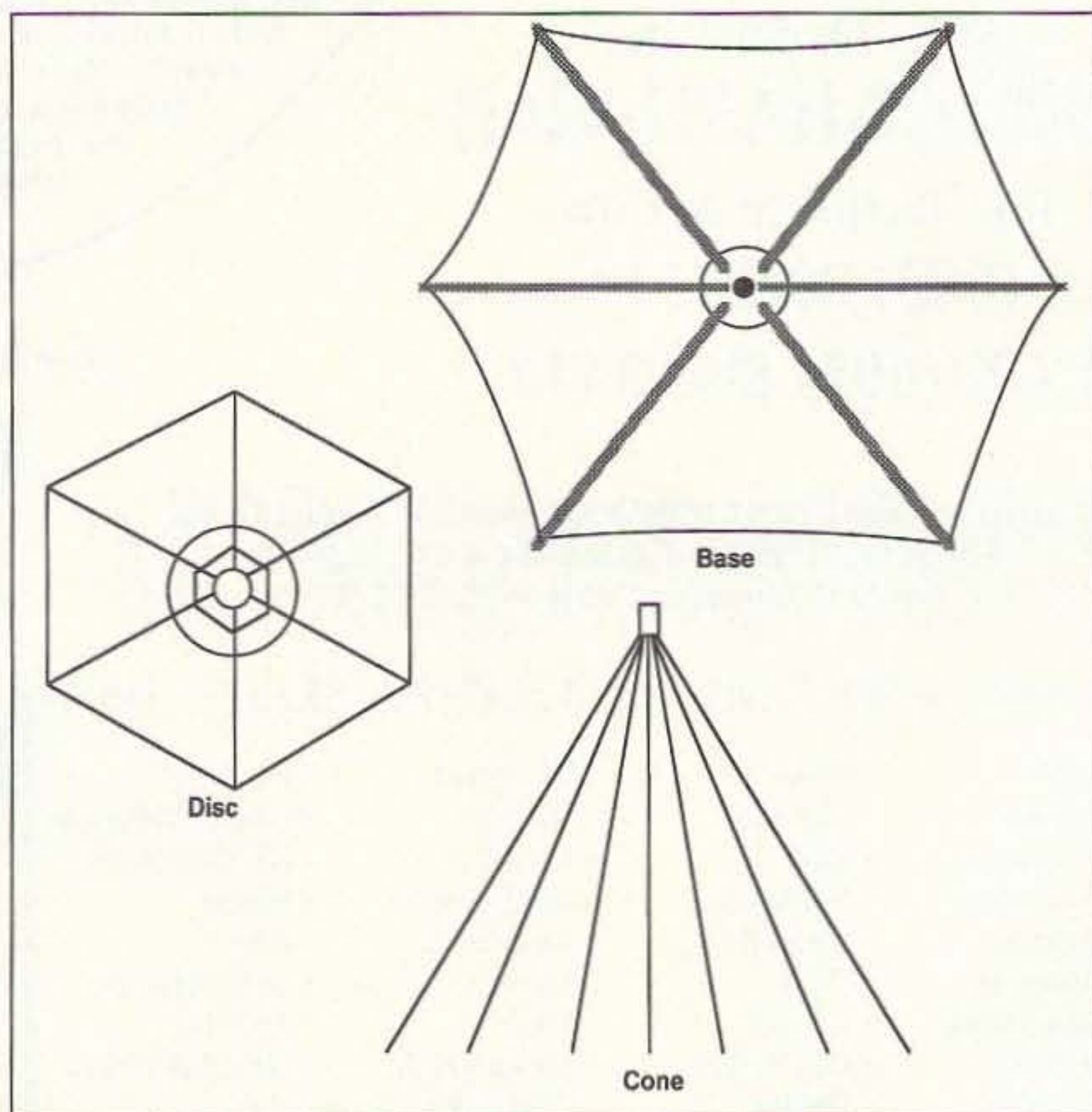


Figure 4. Base, disc, and cone detail.

Discover the Discone

Is this the perfect aerial? Consider simple wire construction, easy one-time tuning, and flat swr from 3.5 to 28 MHz.

With the addition of the new WARC bands, amateur radio operators will have HF allocations at eight

points over an eight-to-one frequency range. Multiband antennas will become quite complicated, except for

broadband types, which will probably become more and more popular. Such antennas as the dipole with tuned feeders, the random wire, the log periodic, and others will be used by many hams in pursuit of multiband operation.

This article describes the theory, design, and construction of a broadband vertical for the range 10 through 30 MHz. This antenna is an adaptation of a technique usually seen only at VHF: the discone. This antenna displays vertical polarization and excellent low-angle radiation; it needs no radial system, and it has a fairly flat, low swr curve over a continuous frequency range. A theoretical swr response is illustrated in Fig. 1.

tudes of the cones are $1/4$ wavelength. The electromagnetic field flows outward from the feedpoint along the surfaces of the two cones until it reaches points separated by $1/2$ wavelength, as shown. Clearly, this will be possible at any frequency larger than $f_{\min}$, provided the vertices of the cones come together precisely at the feedpoint.

As the frequency is moved below $f_{\min}$, it is no longer possible to find two points on the cone surfaces separated by $1/2$ wavelength in space. Consequently, the swr increases rapidly. When the frequency is lowered so that the slant height, h , of each cone is equal to $1/4$ wavelength, we say that the bi-conical antenna is at f_c —its cutoff point. The swr at cutoff varies depending on the vertex angle of the cones. Below f_c , the swr rises with extreme steepness to prohibitively high values. Thus the bi-conical antenna represents an electrical high-pass filter with a lowest practical frequency of f_c .

A bi-conical antenna obviously presents structural problems at high frequencies although it is perfectly practical at VHF. To reduce the physical size of the antenna, the discone was de-

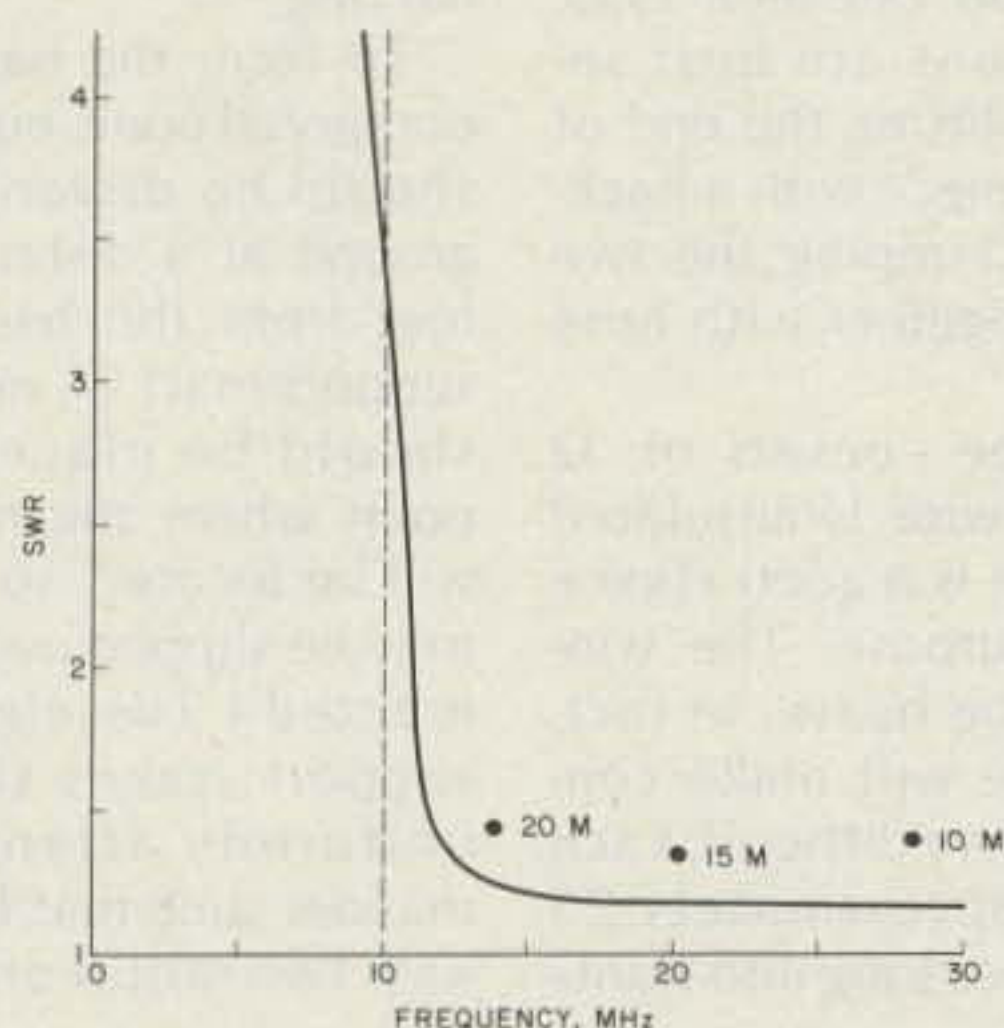


Fig. 1. Swr vs. frequency for a discone antenna having a cut-off frequency of 10 MHz (dotted line). The points show the results of a test at W1GV/4 using the antenna described in this article. Any swr less than 3 was considered tolerable.

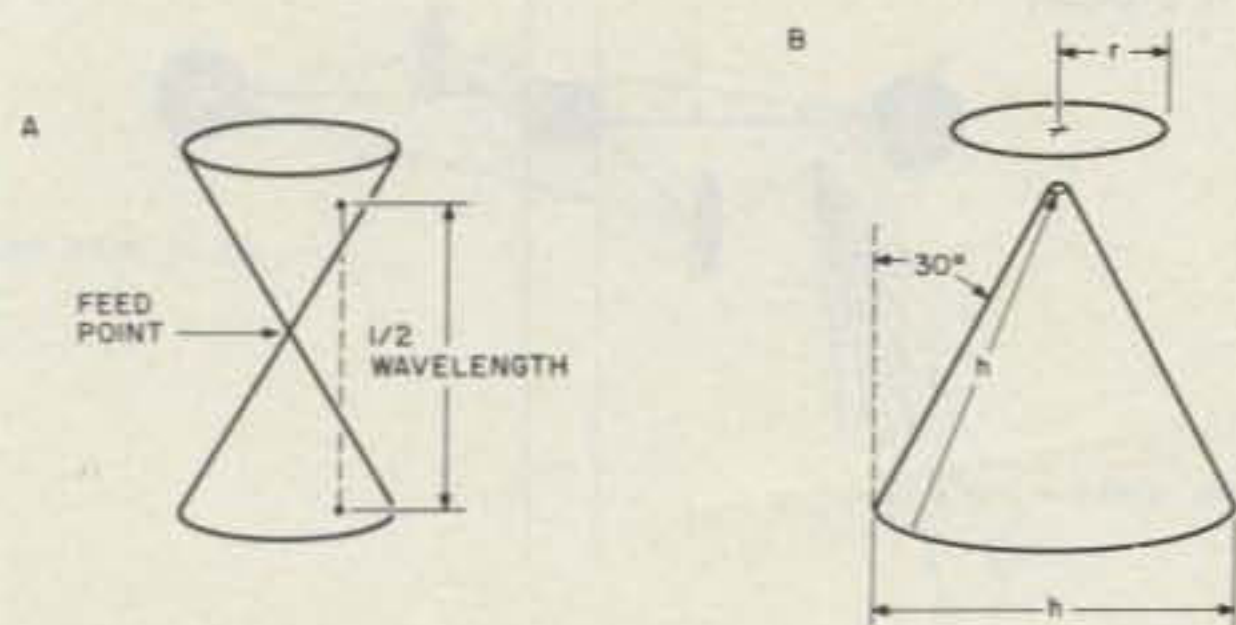


Fig. 2. Design of a bi-conical antenna (A) and a discone (B). The discone is a modified bi-conical antenna, in the same way an inverted ground-plane antenna is a modified vertical dipole.

Theory

The concept of the discone originated with the notion that if an antenna could be constructed whose dimensions were specified by angle measures only, then it would function independently of the wavelength. The bi-conical antenna (A in Fig. 2) is one such device. If the two cones extend sufficiently above and below the feedpoint, then resonance can exist at any frequency above $f_{\min}$, where the alti-

veloped. Either the top or bottom cone may be replaced with a reflecting radial system, and then the antenna will function over the same frequency range (provided the reflector is large enough). If we replace the lower cone with a radial system and bring the feed-point to ground level, we have an antenna known as a conical monopole. By replacing the top cone with a reflecting disk of sufficient size (B in Fig. 2), we obtain the discone. The discone is to the bi-conical as an inverted ground-plane antenna is to a vertical dipole.

The discone is easier to build than a conical monopole primarily because no ground radial system is necessary. The high-current portion of the antenna is elevated above ground. The disk radius need be only about 1/12 wavelength at the lowest usable frequency, f_c .

Design

The antenna gets its name from the fact that it consists of a disk on top of a cone. The disk radius, r , is 0.08 wavelength at the cutoff frequency, f_c , and the slant height, h , is 0.24 wavelength. These dimensions are free-space values.

Above f_c , the swr drops from about 3.5 to almost a perfect match at f_{min} . In theory, the swr then remains nearly constant for several octaves. Above about the

third harmonic of f_c , the maximum radiation begins to occur at considerable elevations above the horizontal; however, between f_c and $3f_c$ the radiation angle is very low and therefore is excellent for DX work.

At 10 MHz, 0.08 wavelength in free space is 7 feet 10 inches, and 0.24 wavelength is 23 feet 8 inches. The slant height of the cone is equal to the base diameter, making the pitch of the cone 30 degrees from the vertical. This value is not, however, particularly critical. Discones may be built with considerably larger or smaller vertex angles. The value of 30 degrees was chosen since it appears to be the most common value in discone design.

At VHF, discones usually are made from solid metal or screen. For a discone with $f_c = 10$ MHz, this would obviously be ridiculous. However, a wire cage will work very well at longer wavelengths provided the separation between the wires is small. The design scheme for the 10-to-30-MHz discone is shown in Fig. 3. A suggested list of parts is given.

Initial Construction

The center support mast for the HF discone is 23 feet 6 inches high. Aluminum tubing works very well for this purpose and is available in most hardware stores. Three eight-foot sections

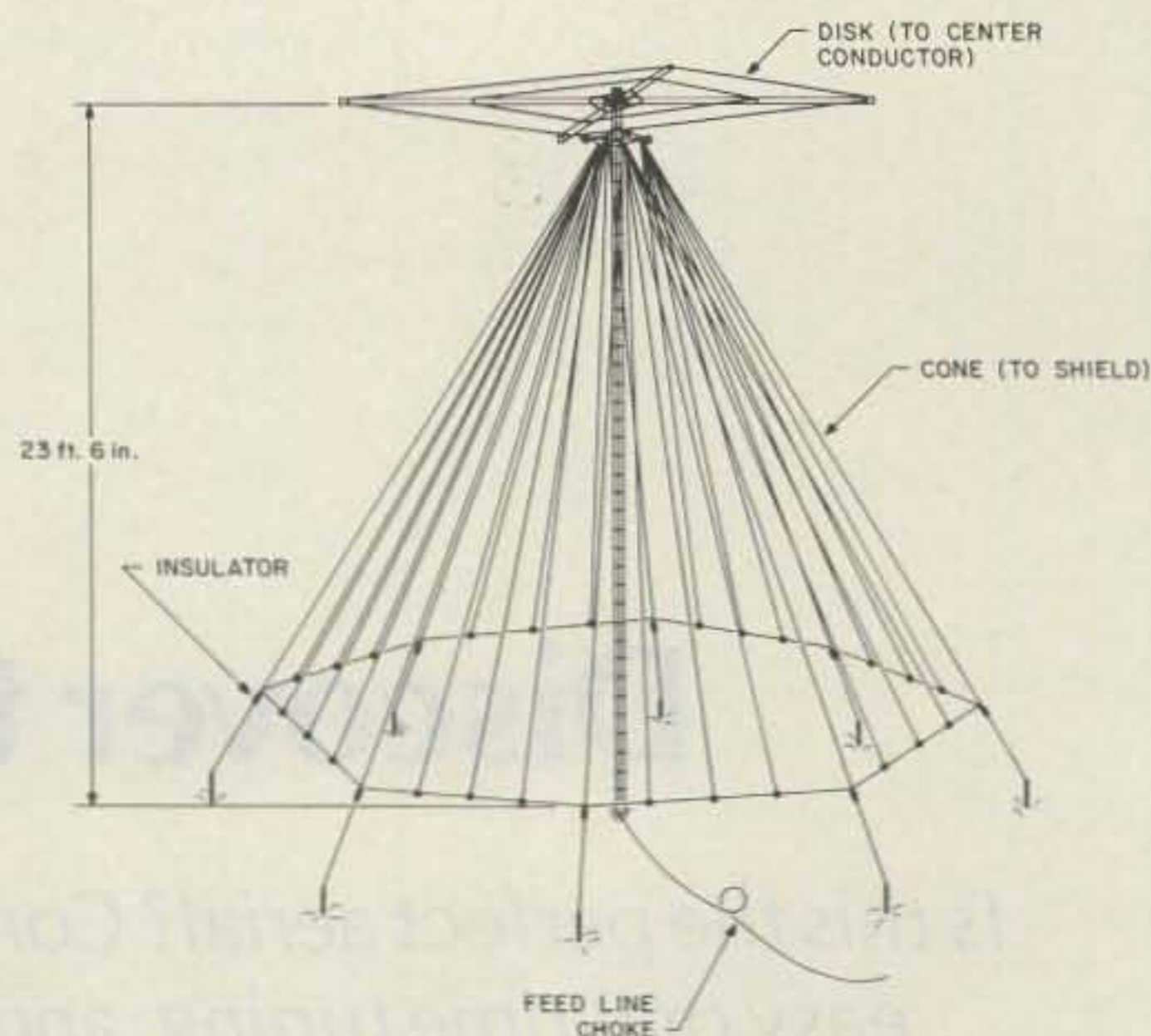


Fig. 3. Construction of the 10-30-MHz discone. The slant height is 23 feet, 8 inches; the square disk has a diagonal radius of 8 feet. The supporting mast is 23 feet, 6 inches high.

may be used, overlapping three inches at the junctions. The top section is one-inch O.D., the center section 7/8-inch O.D., and the bottom section one-inch O.D. The sections are best secured by slitting the end of the larger piece with a hacksaw and clamping the two sections together with hose clamps.

The cone consists of 32 lengths of wire. Uninsulated no. 22 wire is a good choice for this purpose. The wire need not be heavy; in fact, heavy wire will make construction very difficult. Each wire is approximately 23 feet 8 inches long and slants

down at an angle of about 30 degrees with respect to the vertical mast. All the wires are joined at the base of the cone with an octagonal ring.

To form the base of the octagonal cone, eight stakes should be driven into the ground at a distance of 15 feet from the base of the support mast. (A ninth stake should be placed at the point where the mast base will be located, so the mast may be slipped over it when erected.) The eight cone-support stakes should be uniformly arranged in a manner such that lines from any two adjacent stakes

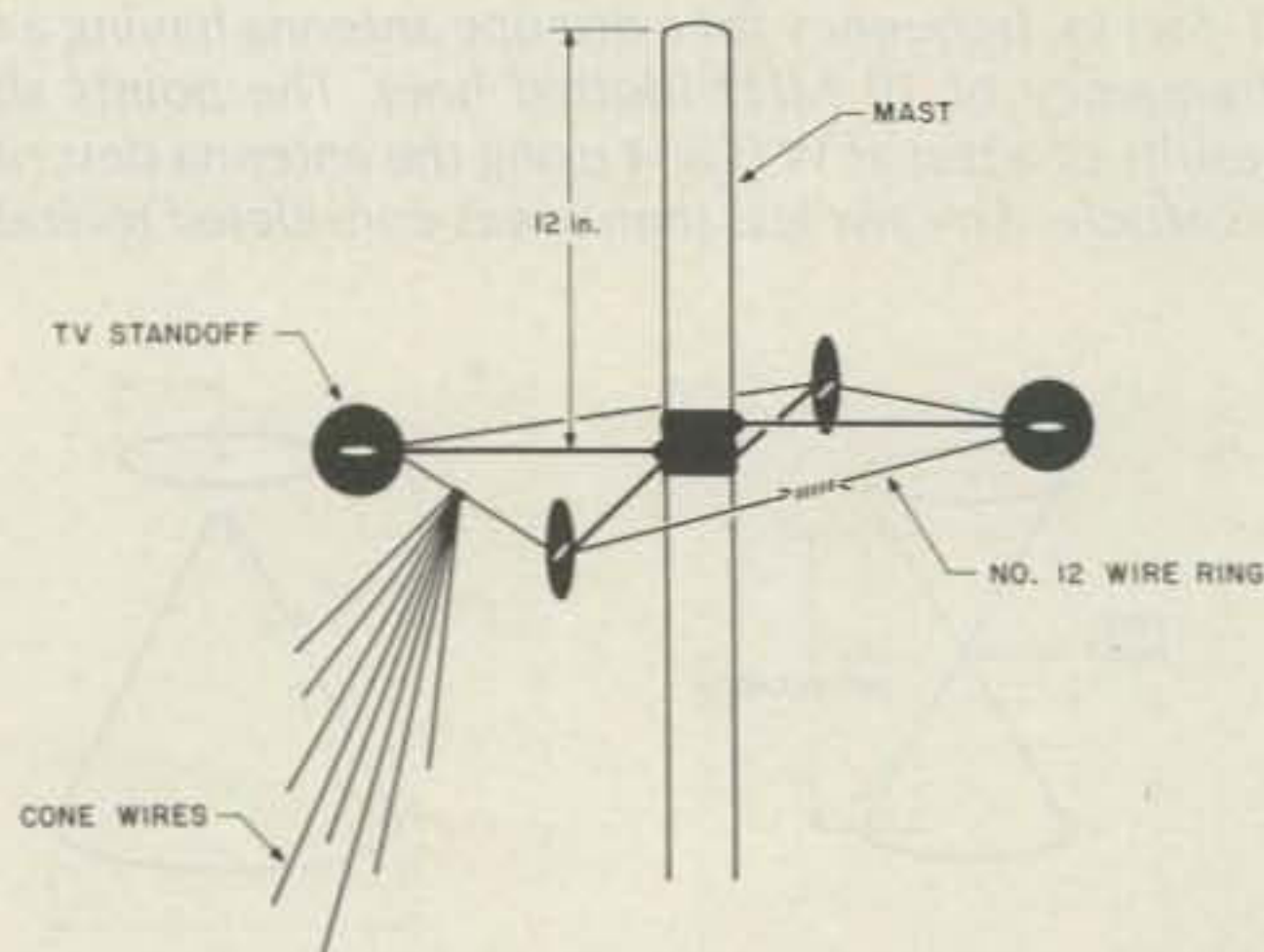


Fig. 4. The ring for the apex of the cone is constructed using no. 12 wire and four clamp-and-screw-type TV standoff insulators. The cone wires are attached in bunches of eight, one bunch to the center of each side of the square.

f_c , MHz	Bands covered, M	r , ft.	h , ft.	Mast*
3.4	80, 40, 30, 20, 17, 15, 12, 10	23.1	69.5	65
6.9	40, 30, 20, 17, 15, 12, 10	11.4	34.2	33
10.0	30, 20, 17, 15, 12, 10	7.9	23.7	23
13.7	20, 17, 15, 12, 10	5.7	17.1	17
17.9	17, 15, 12, 10	4.4	13.2	13
20.5	15, 12, 10	3.8	11.5	11
24.0	12, 10	3.3	9.9	9
27.0	10	2.9	8.7	8

* Minimum heights, in feet.

Table 1. Discone dimensions for various frequencies f_c . (Values of f_c are chosen slightly below the lower end of the nearest amateur band.)

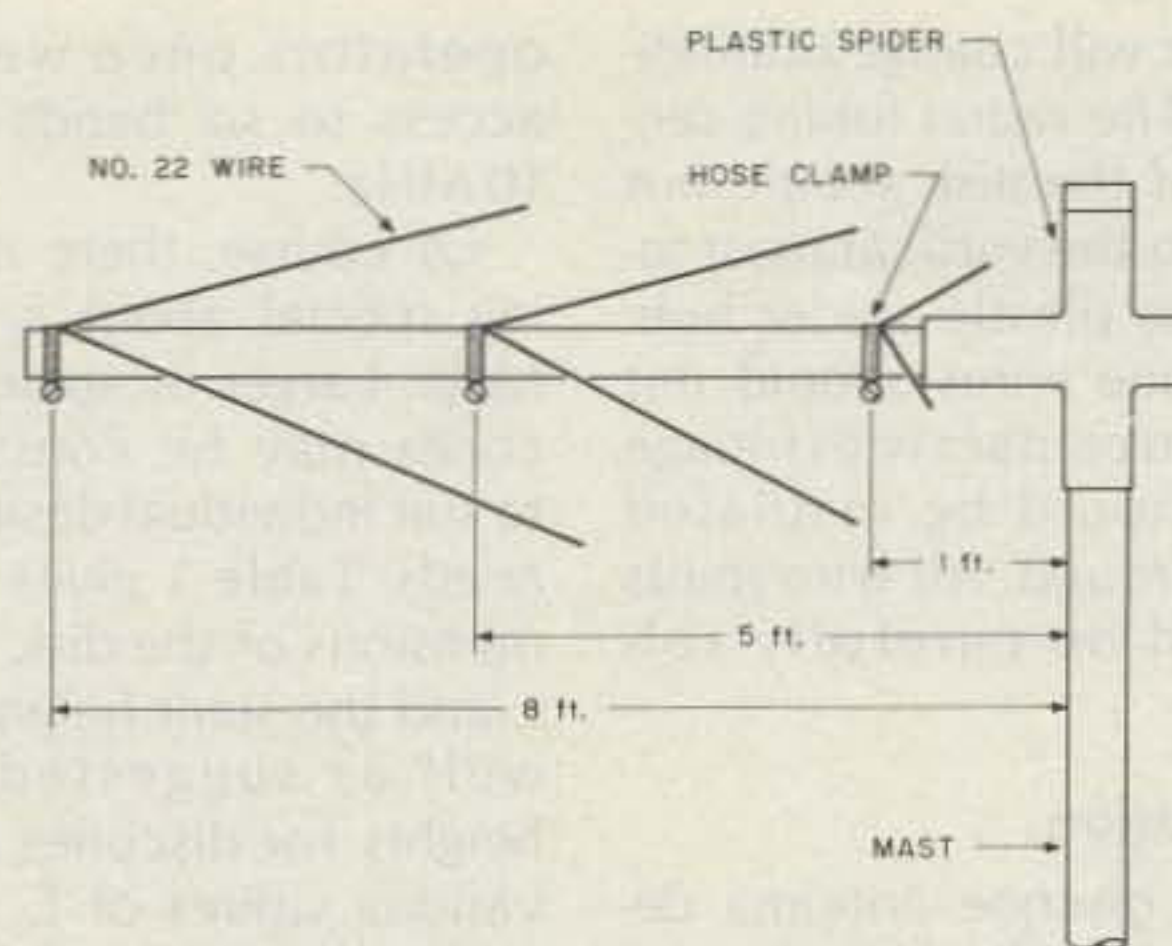


Fig. 5. Radial leg of square disk. Three concentric square rings of no. 22 wire join the radial tubing sections. The disk is mounted at the top of the mast using a plastic quad spider. The mast is wrapped with electrical tape to ensure a tight fit for the spider and also to insulate the disk radials from the mast.

would form a 45-degree angle at the center support point.

The cone apex is constructed as shown in Fig. 4. Four clamp-and-screw-type Radio Shack TV standoff insulators are mounted about one foot below the top of the mast. A length of no. 12 uninsulated solid copper wire should be run through the standoff holes and soldered at the ends to form a square. Caution must be exercised to make sure the ring does not short to the metal parts of the standoffs (and thus to the vertical mast).

To complete the cone, cut 32 lengths of no. 22 wire, each 24 feet long. Solder them in bunches of eight to the center of each side of the apex square. This prevents them from becoming

hopelessly snarled when the mast is put up. Have someone hold the top section of the mast upright at its eventual location and fan the cone wires out along the ground in a uniform radial arrangement.

The "disk" is made from four eight-foot sections of one-inch O.D. aluminum tubing, a quad spider, twelve hose clamps, and more no. 22 wire. Insert the four sections of tubing into the spreader holes of the quad spider so that they form an X. In Fig. 5 we see how the wires are attached to the four radial sections of tubing to form the square disk. The wires should be pinched into a small U shape at each point where they are clamped to the tubing. Three concentric wire squares will

result. The wires should be straight but not under strain since they will contract in cold weather. Mount the square disk at the top of the support mast, using the spider. Wrap the mast with tape to get a tight fit.

Putting It Up

Attach the center conductor of the coaxial feedline (RG-58/U, RG-8/U, or equivalent) to the center of the disk, using a hose clamp at the innermost exposed metal point of one of the radial tubing sections. Attach the outer conductor to the apex of the cone.

Have someone hold the top section of mast, complete with cone wires and disk attached, at the point where the mast is to be erected. Attach two of the cone wires from each bunch to adjacent radial stacks, using an insulator and four extra feet of wire. Raise the mast to its full height while keeping it vertical (a stepladder is almost a necessity to do this!). Tape the coaxial feedline to the mast as it is raised. Once the mast is fully extended, tighten the eight cone wires so that the mast is vertical and is effectively guyed by the wires—but don't pull them excessively tight.

Construct a ring of wire by connecting the eight cone wires together immediately above the insulators. This octagonal ring will be two or three feet above the ground. Then attach the remaining radial wires to the ring in uniform fashion all around. As with the other wires, do not pull them too taut. Each bunch of eight radial wires should run to two adjacent sides of the octagonal cone ring.

The feedline should be decoupled from the antenna at the point where the cable crosses under the cone ring. Otherwise there may be antenna currents on the feedline, with consequent problems. Wind the cable into a tight coil about five or six

inches in diameter with 10 to 15 turns. This will choke off unwanted currents on the outside of the coaxial cable while leaving its performance as a feedline unaffected.

Testing

Once the discone is complete, you are ready to test it for swr. Results of testing at W1GV/4 are illustrated by the points in Fig. 1 at 14, 21, and 28 MHz. The swr is expected to begin rising at about 12 MHz. In theory, it should be about 3.5 at 10 MHz.

If the swr is a bit higher or lower than the values shown in Fig. 1, it is probably because of the ground conductivity (which can range from rotten to excellent) and also perhaps because of objects such as trees and electrical wires in the near field of the antenna. In some cases, sharp increases in swr may appear mysteriously at certain frequencies well above f_c . These cases are usually attributable to resonances in nearby objects such as other antenna towers and masts. Keep the discone as far away as possible from other antenna structures.

Since the discone is a vertically-polarized antenna and has a broadband response, it may pick up more man-made noise than resonant (narrowband) or horizontal antennas. A transmatch at the station end of the feedline will give the discone some selectivity, which should help reduce this noise if it is a problem. The transmatch also will reduce harmonic radiation. Hopefully, your transmitter has enough harmonic attenuation already, but the discone offers none at all.

If the swr is not reasonably low and flat (2 or less above f_{min}) and there are no known resonant structures nearby, check to be certain there are no open or short circuits in the system. If the cone apex ring should happen to touch the metal part of one of the TV standoffs,

Parts List

Aluminum tubing, 7/8" O.D., 8' long	1
Aluminum tubing, 1" O.D., 8' long	6
Electrical tape, large roll	1
Ground stake, 2' long, minimum	9
Hose clamp, 1-1/4"	15
Insulator, porcelain or glass, 4"	8
Spider hub, plastic*	1
Standoff, TV type, clamp-and-screw	4
Wire, uninsulated no. 22, 1000 ft. roll**	1
Wire, uninsulated no. 12, 5-ft. length	1

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the swr will change dramatically. The radial tubing sections of the disk should not short to the vertical mast inside the plastic spider hub. The cone wires should not come in contact with foliage and should be insulated from ground. All wire joints should be carefully soldered.

Conclusion

The discone antenna described in this article was built and tested at W1GV/4 in the summer of 1981, at which time I had the good fortune to be able to use nearly an acre of real estate. Results were as expected. The antenna performed very well for DX on 20, 15, and 10 meters. This is undoubtedly because of the low angle of radiation and the fact that the feedpoint is well elevated above the level of most nearby obstructions, especially houses (which are almost all single-level structures in Florida!). The discone should be a great convenience for multiband

operators once we have access to six bands above 10 MHz.

Of course, there is nothing special about $f_c = 10$ MHz. Larger or smaller discones may be constructed to suit individual desires and needs. Table 1 gives the dimensions of the disk radius, r , and the slant height, h , as well as suggested mast heights for discones having various values of f_c . A discone for 80 through 10 meters is not out of the question if you have a 65-foot tower and a strong pair of legs! The disk, while quite large, could be supported with nylon rope trusses. A lot of wire would be needed for the cones! For serious low-band DXers, though, such a system could be more than worth the effort. ■

References

Bill Orr, *Radio Handbook* (nineteenth edition), Howard W. Sams & Co., Inc., 1972.
Reference Data for Radio Engineers (sixth edition), Howard W. Sams & Co., Inc., 1975.



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The Discone Revived

What is a discone antenna? It consists of a disc and a cone, Fig. 1. In its purest form, both the disc and the cone are fabricated from sheet metal. The coaxial line is fed up the central area of the cone. The inner conductor connects to the center of the disc; the braid, to the point of the cone. The dimensions shown go back to Kandoian's research conducted prior to 1946. Calculation is based on the lowest frequency of desired operation. A discone antenna maintains a low impedance over a wide span of frequencies that begin at its low cutoff frequency. As a result it will have good pick-up over a great bandwidth. A discone designed for a specific low HF or VHF frequency cutoff may have a bandwidth that extends to a frequency 50 or more times higher. The response drops off quickly on the low frequency side of cutoff.

Practical discons can be fabricated from tubing, rods, wire, and even netting such as screening or hardware cloth. By proper choice of lengths, a reasonable bandwidth can be obtained. Also, very simple discons can be designed and element lengths can be chosen to zero in on specific bands that lie within a broad frequency span.

A rod version of the discone is the Diamond D130, Fig. 2, which consists of eight rods that form the disc and eight longer ones

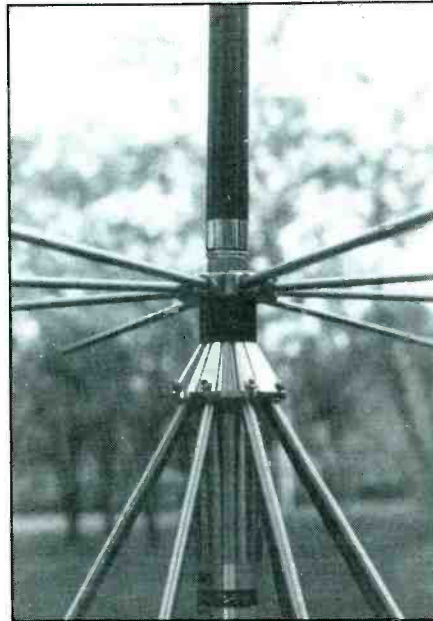


Figure 2: Diamond D130 construction.

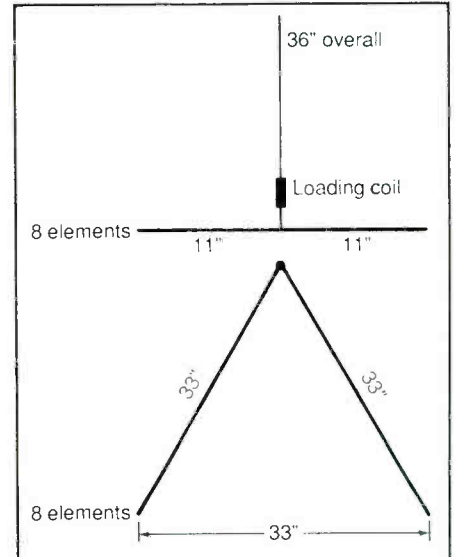


Figure 3: Approximate dimensional plan of D130.

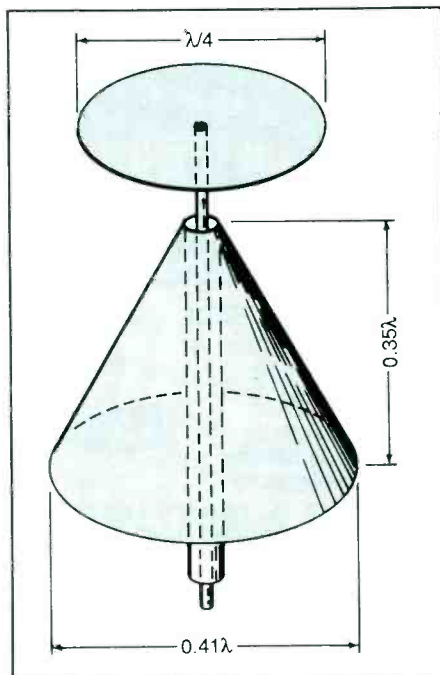


Figure 1: The basic discone.

that droop away into a cone. The approximate lengths are given in Fig. 3. The transmission line feeds up inside the center tubing to the coaxial fitting mounted just below the center insulator. Bandwidth extends between 25 and 1300 MHz. It is really an all-band scanner antenna with performance at the low end of the VHF band assisted by the base-loaded vertical that screws into the top of the discone.

Receive pick-up is good over the designed range. On its low frequency side, the pick-up remains reasonable on the 11 and 13 SW bands and even the 15 meter Ham band. The Diamond D130 does zero in on the 50, 144, 430 and 904 MHz Amateur bands with an impedance of 50 ohms for matching Ham transmitters.

The Antenna Specialists MON-64, Fig. 4, is inexpensive and is just a mere skeleton of a discone. But with its proper element length, Fig. 5, it does a fine job on the 150, aviation, and 450 bands and is sometimes down slightly on 50 MHz. This latter condition might be a less than uniform omnidirectional pattern on this band associated with the relative positioning of the disc and cone rods. The approximate length of the disc element is 20"; cone element, 45".

The construction plan of the MON-64 is visible in Fig. 5. The three disc elements fasten to the top and are linked electrically to the inner conductor of the coaxial connector down the center of the short cylindrical insu-

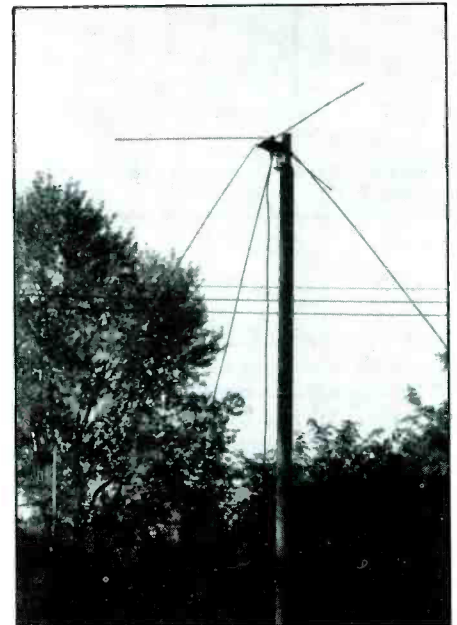


Figure 4: A shot of my Antenna Specialists' MON-64 Discan™.

lator. The actual connector is a part of the plate portion of the cone bracket and transmission line connection is made directly beneath the plate. The three cone elements also attach to the plate.

Such discone-derived antennas fasten readily to 1" ID plastic piping and permit easy attachment to chimney straps, wall mounts, and roof brackets. Good perfor-

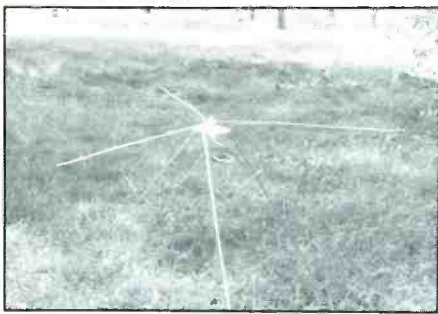


Figure 5: Basic construction of MON-64.

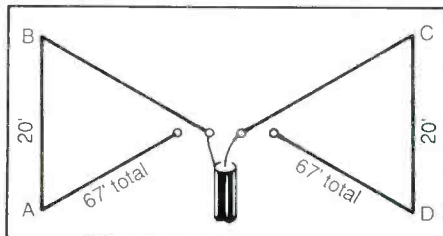


Figure 6: Shawn Axelrod's bow-tie dipole.

mance over a wide bandwidth is their thing. Maybe some homebrew versions of the disccone will be forthcoming. Are you interested out there?

Wideband Bow-Tie For Radio Listening

Here is data that a neighbor from Winnipeg, Manitoba sent in early 1986. I had hoped to do a story on folded antennas and include this material. Much time has past and I'm presenting Mr. Shawn Axelrod's details while we are on the subject of wideband antennas. The antenna is a folded one in an open bow-tie configuration, Fig. 6. He has fit it into his 50' lot.

Points A and B are about 20' apart and are tied to the base of the peaked portion of his roof. The opposite points C and D are supported by two 20' masts. The center insulator is a 10" by 2½" plastic piece with appropriate holes for supporting the antenna wires. Terminals for the transmission line are mounted at the center and permit attachment of the coaxial line. The two returning ends of wire are tied off individually and do not make any electrical connection. The total length of the wire on each side is about 67', corresponding approximately to a quarter wavelength on 80 meters.

Actually, Shawn is a Ham radio, SWB and BCB listener. His loggings with the antenna follow, beginning with his main interest of Ham radio listening.

Ham: 317 countries and 40 zones with 7 countries on the very low frequency 160 meter band.

SWB: 115 countries (all continents).

BCB: 200 USA, 52 Canada and 10 Mexico stations.

Great, Shawn, and I'm sure you added more during the year past. We thank you for the helpful information.



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BY LEWIS KESEBERG

What with the newer scanners arriving on the scene all set to cover enormous chunks of frequency spectrum, my rooftop had started to look a bit like the control tower at a major airport. With a CB antenna, one for the 30 to 50 MHz "low band," another for the 150 to 174 MHz "high band," plus a few special-purpose antennas, things were getting crowded.

The concept of combining virtually all of my requirements into one single ultimate wideband antenna eventually crossed my mind. No matter how many chunks of metal and wire you shove into the air above your house, I suppose you never really stop searching for something that approaches being that impossible, ultimate type of sky-hook, especially when you know that each band and radio service calls for a different shape and size.

On the other hand, the discone antenna—originated almost 50 years ago and rediscovered recently—comes awfully close to being the answer to my search. It offers a near-perfect match to 52-ohm coax cable, an operating range of 10-to-1 in frequency, and freedom from any critical tuning adjustments. It has low wind resistance and, despite what you might think from looking at it, the discone is vertically polarized. Another plus is that it offers greater ground-wave coverage than many other vertically-polarized antennas. This comes about because its most effective portion is located right at the top of the pole; other types of vertical antennas have their most effective portions part-way down the mast which usually results in a closer "communications horizon."

Okay, this isn't an amazing revelation. Discones are available commercially, such as the one offered by Encomm, Inc. (2000 Avenue G, Suite 800, Plano, TX 75074), so nothing I've said thusfar should come at you like a bolt from the blue. On the other hand, perhaps you'd like to try scratch-building one of these devices, and that's where I come in.

Building A Discone

Before starting construction, it's best to know just what a discone antenna is and what it is supposed to do. Basically, the dis-

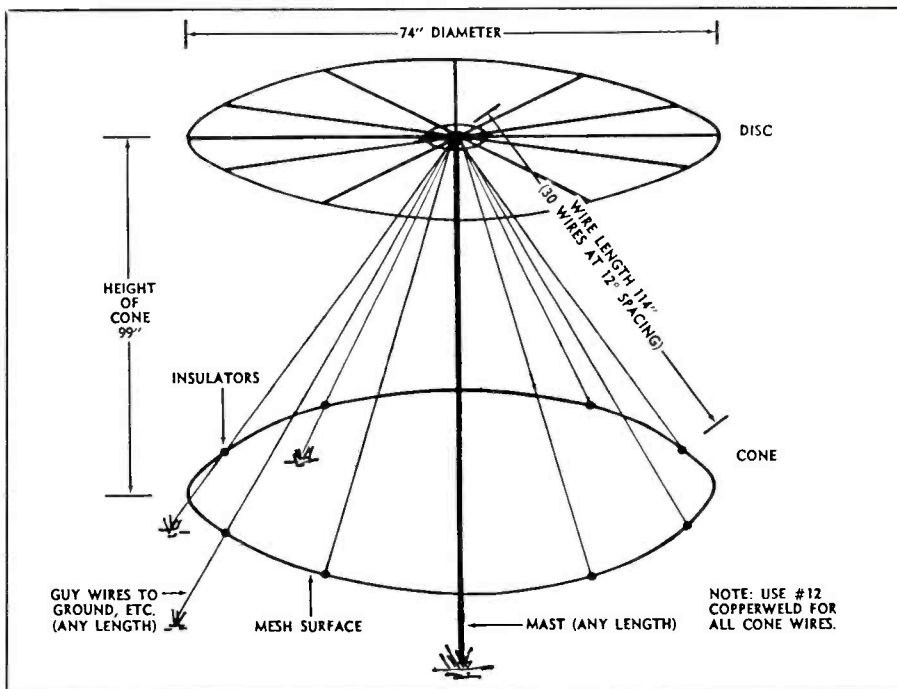


Figure 1: Discone, overall view.

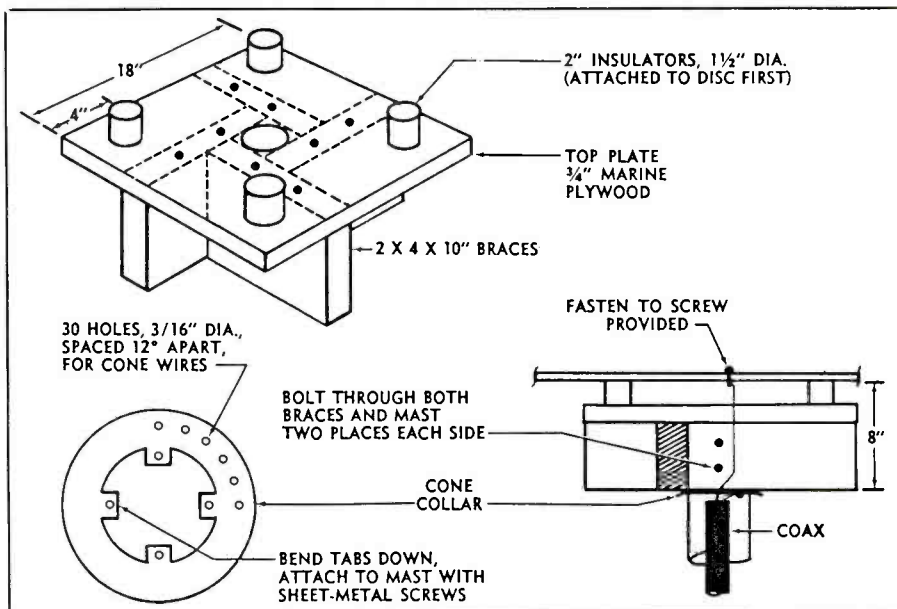


Figure 2: Insulator details.

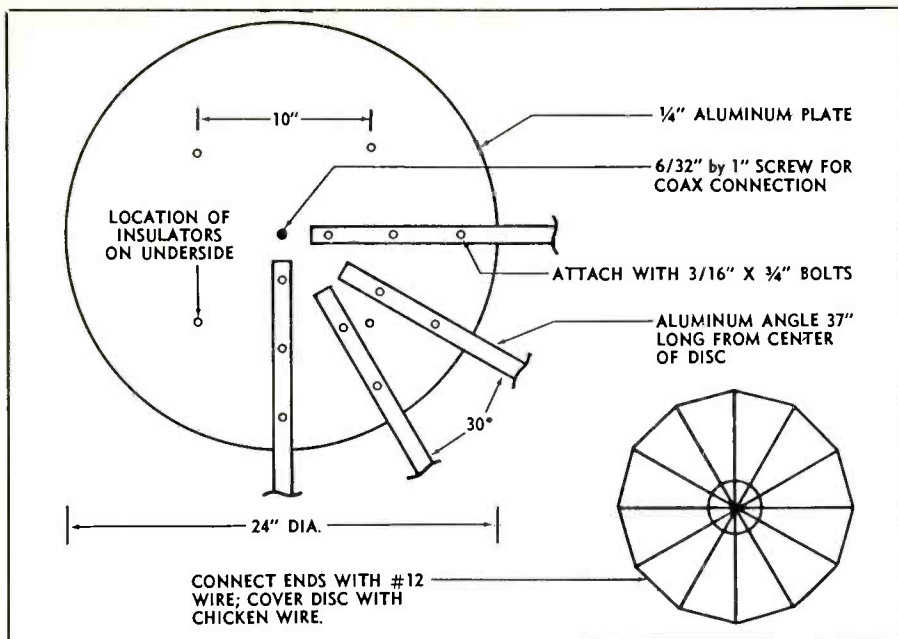


Figure 3: Details of disc assembly.

cone consists of an inverted (with the point towards the sky) metallic cone with a large disc (also metallic) balanced on the point. The disc is really fastened firmly, and insulated instead of balanced—but at any distance it looks like a balancing act (see Figure 1).

The coax feed line comes up inside the cone. The shield of the coax connects to the cone, and the center conductor connects to the disc. Thus, the cone becomes a continuation of the shield, while the disc becomes a reflector connected to the center wire.

In practice, outgoing RF energy hits the disc and is reflected out the open side of the affair. If the "slant angle" of the cone sides is correct, though, the outgoing signal can't tell what's happening to it and the SWR will be down to 1.0.

The important things electrically, then, are to keep the slant angle of the cone sides proper and to keep the top disc level. Good insulation between disc and cone at the center is also essential.

Mechanically, an 11-meter discone is quite an impressive array and could offer much, much wind resistance. If you built one out of solid sheet metal, the first breeze would tend to whip it away like a sail. However, a fine-mesh screen looks to RF like a solid sheet of metal if—and only if—the spacing between conductors in the screen is small compared to the wavelength of the RF. This is the key to our construction.

For instance, a screen spacing of 0.01 wavelength is plenty close enough to look solid to RF. Yet at 11 meters this becomes a spacing of 0.11 meter or 4 1/2 inches (approximately) so that you could use very coarse fencing mesh for lowest wind resistance.

Best results were obtained with a type of fencing usually called "chicken wire" screening. This has a hexagonal screen pat-

tern about an inch wide between conductors. You can use it for the surface of both the cone and the disc, cutting wind resistance to an absolute minimum.

However, the chicken wire is too flexible to stand up by itself. You must put a framework behind it for support. Wooden framing is okay, but aluminum angle stock is just as easy to work with and lasts longer.

The only really tricky part about the whole antenna is construction of the insulator that goes between the disc and the cone. It's shown in detail in Figure 2; follow the drawing closely and you won't go wrong.

Actual construction procedure is as follows: First, put up your mast. It can be any length greater than 10 feet. Next, fasten the insulator-and-guy-ring structure to the top of the mast. Now, connect the coax to the insulator-and-guy-ring assembly. Put together the disc assembly on the ground and get it into position on the insulator aloft (this may require some help). As a safety measure, DO NOT erect this anywhere near the powerlines as it could cause a severe hazard if it should topple over into those lines. Attach the guy-wires to the assembly and secure them at anchor points selected so as to give the proper slant angle. Finally, cover the guy-wire structure with chicken wire, soldering the joints, and you're ready.

The disc assembly referred to above is shown in detail in Figure 3. It should be completely assembled on the ground and lifted to the top of the pole before securing to the insulators—otherwise, the affair will be too top-heavy.

When you're finished, hook the other end of the 52-ohm coax to your communications gear and fire up. If you intend to use this for several different bands and purposes, do not have any scanners or other receivers connected and operating from the discone while you are transmitting.



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General Purpose VHF/UHF Antenna

This is a good, cheap broadband antenna that can be built in a weekend, and it's great for those who don't have a lot of space.

Winter storms wreaked havoc with my scanner antenna and I needed to find a replacement.

I was attracted to the discone. This type of antenna, when properly designed, is capable of operating over a 10 to 1 frequency range. With this range an antenna designed for low-end operation of 100 MHz is usable up to one GHz.

I was turned off by the cost of the commercial version; it cost nearly what I had paid for the scanner! So, I decided to build one myself. I did, however, avoid parts that needed special machining.

This project is simple to build and requires only basic tools and readily available materials (see Parts List). The basic antenna, along with the formulas for determining the lengths of the various elements, is shown in Figure 1. The RSGB VHF/UHF Manual was my reference. I decided that a low-end frequency of 108 MHz would be desirable, since this is the low end of the aircraft band covered by many of the new scanners. This allows maximum utilization of the brazing rods. The parts are cut, drilled, and assembled as shown in Figures 2 and 3.

The results have been encouraging—the

swr on the amateur frequencies between 144 and 450 MHz is less than 2.5:1 over the entire range. When measured at the end of a 50-foot piece of coax, the swr is 1.5:1 or better. Spot-checks on various commercial frequencies gave similar results. A modified version provides adequate receive coverage on the VHF low (30–50 MHz) public service frequencies.

Construction details are as follows:

108–145 MHz

1. Cut the brazing rod to dimension A (27").
2. Prepare the brass pipe cap—drill and tap

- A Cone Element Length = $2952/F(\text{MHz})$
= 27 inches.
B Disc Diameter = $A \times .7 = 19$ inches
C Cone Diameter = as small as possible.
Here is 1.25 inches.
D Space between disc and cone = $.2 \times C$
= .25 inches

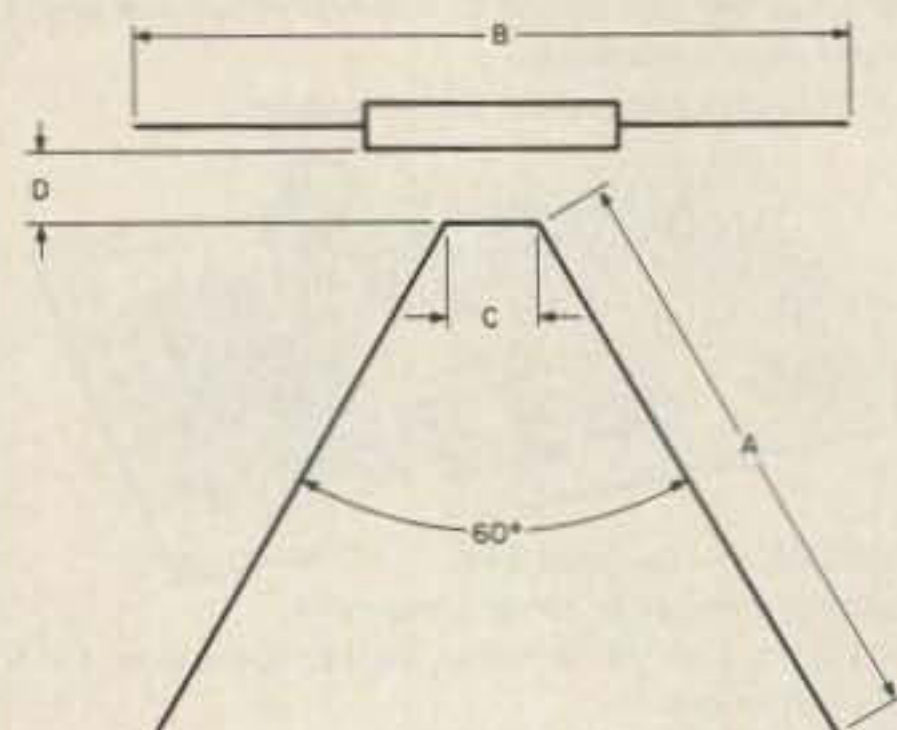
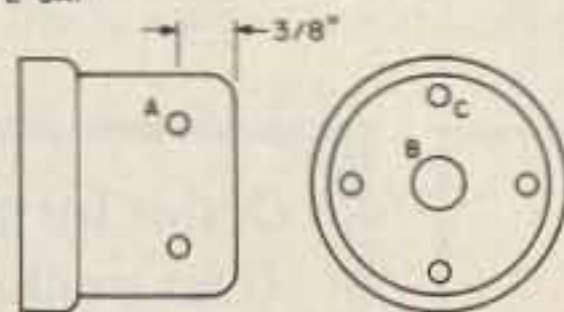


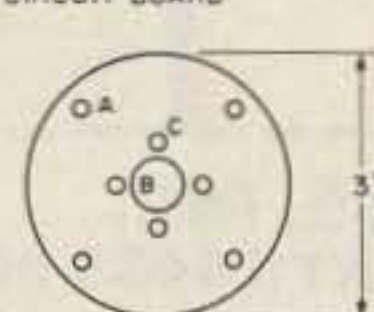
Fig. 1. Schematic diagram of the antenna and formulas for determining the lengths of the elements.

PIPE CAP



- A- 8 HOLES $\times 1/8"$ EQUALLY SPACED ABOUT PERIMETER. DRILL THRU.
B- DRILL THRU $5/16"$ DIAMETER.
C- 4 6-32 HOLES. DRILL AND TAP THRU ON $1"$ DIAMETER.

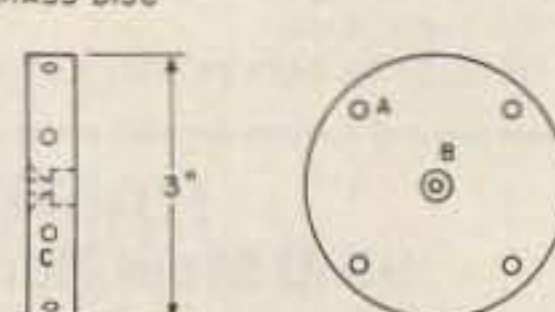
1/4 in. CIRCUIT BOARD



- A- 4 6-32 HOLES. DRILL THRU ON 2.5 DIAMETER.
B- DRILL THRU $5/8"$ DIAMETER.
C- 4 6-32 HOLES. DRILL THRU ON $1"$ DIAMETER.

NOTE: FOR VHF LO MODEL, COUNTER-SINK C HOLES ON TOP SIDE AND THE A HOLES ON THE BOTTOM SIDE.

BRASS DISC



- A- 4 6-32 HOLES. DRILL AND TAP ON 2.5 DIAMETER.
B- DRILL THRU $3/16"$ DIAMETER THEN DRILL AND TAP $3/8" \times 24 \times 3/8"$ DEEP.
C- 8 $1/8" \times 1/2"$ DEEP HOLES. EQUALLY SPACED ABOUT PERIMETER. COUNTERSINK $3/16"$ HOLE.

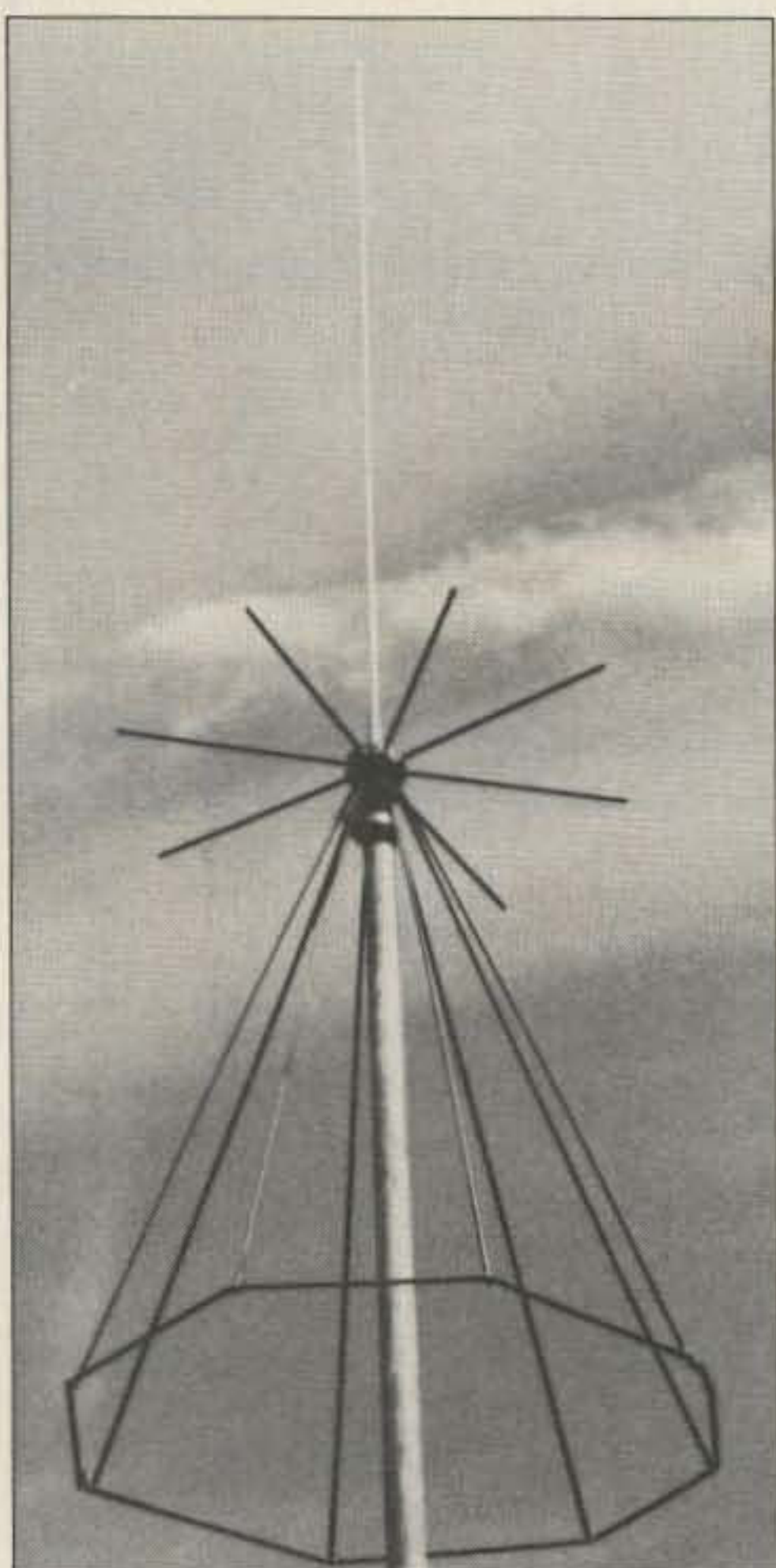


Photo A. The WA1GPO home-brew VHF/UHF discone antenna.

Fig. 2. Top and side views of the base assembly for the elements and vertical whip.

all holes, buff clean, and file the top of the cap flat.

3. Bend the elements to the desired 30° angle, and solder the elements on the cap.
4. Install the BNC connector in the cap.
5. Trim the circuit board to size, drill the mounting holes, and solder the remaining pieces to the brazing rod in position to form the disc, then trim the disc to a 19" diameter.
6. Attach the disc to the brass cap with nylon screws, and solder the center conductor of the BNC connector to the disc, and seal the connector hole with silicone sealer.

VHF Low and 108-450 MHz

Complete steps 1 through 4 above.

5. Trim the circuit board to size, drill and countersink all holes, mount the BNC connector on the cap, and mount the board to the brass cap with flathead s.s. screws.
6. Prepare the brass disc—drill and tap holes as required, and solder the remaining pieces of rod to the brass disc.

7. Solder a 3" piece of #18 solid wire to the BNC connector, and mount the brass disc to the circuit board using flathead s.s. screws.
8. Coil the 3" wire in the 3/8" hole, and install the modified CB whip, and trim 4" off the antenna.

The antenna can be installed using conventional pipe. In the low frequency version, the lower section of the pipe should be 84 inches long. This 84-inch section is the lower half of the sleeve dipole, and should be isolated from the mast to which it is mounted. You should select a good grade of coax to minimize the line loss; RG-59 BNC connectors fit well on RG-8X 50-Ohm cable.

Two final notes: Be careful when drilling the soft brass as it tends to "grab," and, as with any broadband antenna used for transmitting, a low-pass filter on the transmitter is recommended to minimize harmonic radiation. The photo shows the details of the disc-cone construction. ■

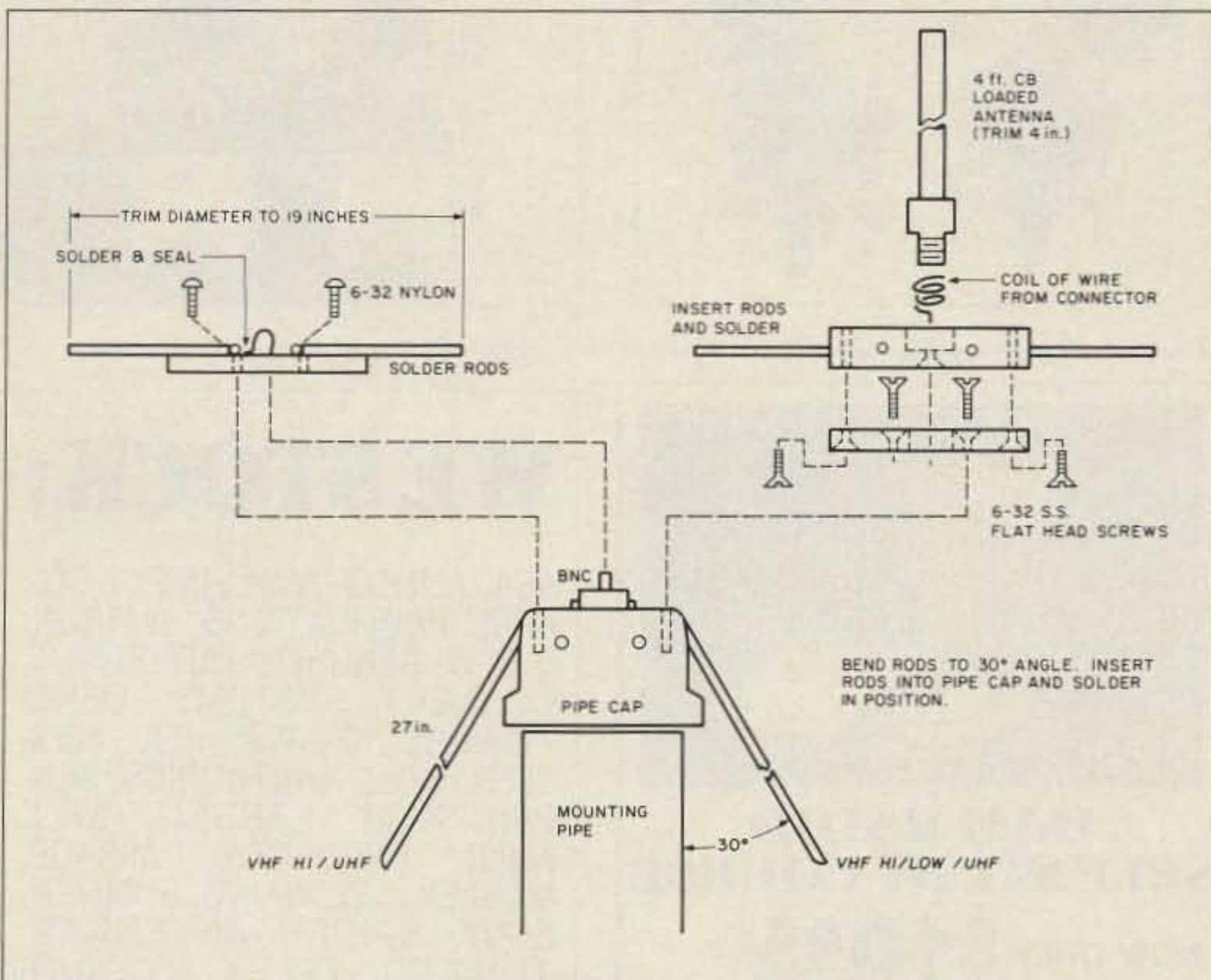


Fig. 3. Blow-up side view of the element base assembly.

Parts List

1. 1" brass pipe cap
2. BNC chassis mount connector (Radio Shack 270-105)
3. 1/4" glass epoxy circuit board, with a 3" diameter
4. 1/8" x 36" brazing rod (8 ea.)
5. 60/40 rosin-core solder
6. 6-32" x 1/2" nylon screws (4 ea.)
7. Silicone seal

Low Frequency Version

Items 1 through 5 same as above

6. 6-32 x 1/2" stainless flathead screws (8 ea.)
7. Brass disc, 3" diameter x 1/2"
8. 4' loaded CB antenna (Radio Shack 21-934)

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CIRCLE 192 ON READER SERVICE CARD

Chicken-wire Discone

The discone wide-band antenna has been around for many years, but unfortunately it's been portrayed too often as a complex mechanical design. This is rather sad as the antenna is a good performer and has lots of latitude for mechanical variation, as Tony Gilbey G4YTG shows in the following article.

An experimenter friend of the author wrote to him recently asking if he had a discone design which could be built for installation in the loft.

Eventually a copy of an article that appeared in an American magazine was dispatched, showing a skeleton type discone using aluminium rods to form the antenna elements. The author pointed out that if the antenna was to be installed in the loft, the design need not be so mechanically rigid, this is when the G4YTG cheap chicken-wire discone was born.

The antenna's performance so surprised the author that he felt he had to pass on the design to his fellow amateurs. The design is ideal for those people that prefer to put their antennas in the loft and who also have an aversion to spending lots of money on antennas.

All that is required to build the project is approximately £6 for materials, a large soldering iron, pliers and a pair of tin snips.

The author's loft mounted, chicken-wire discone provides wide-band omnidirectional coverage of frequencies from 75MHz to 800MHz, as well as

showing a v.s.w.r. of better than 1.2:1 when used in conjunction with 144MHz and 430MHz transmitters.

Construction

First unroll the wire mesh and cut out the shapes to the dimensions given in Fig. 1. Next lay the "cut edge" of one of the large pieces over the wire edge of the other to make a semicircle shape, and "blob-solder" together at every other loop crossing. Then form the semicircle of wire mesh up into a cone shape and solder down the other overlapped joint in a similar way.

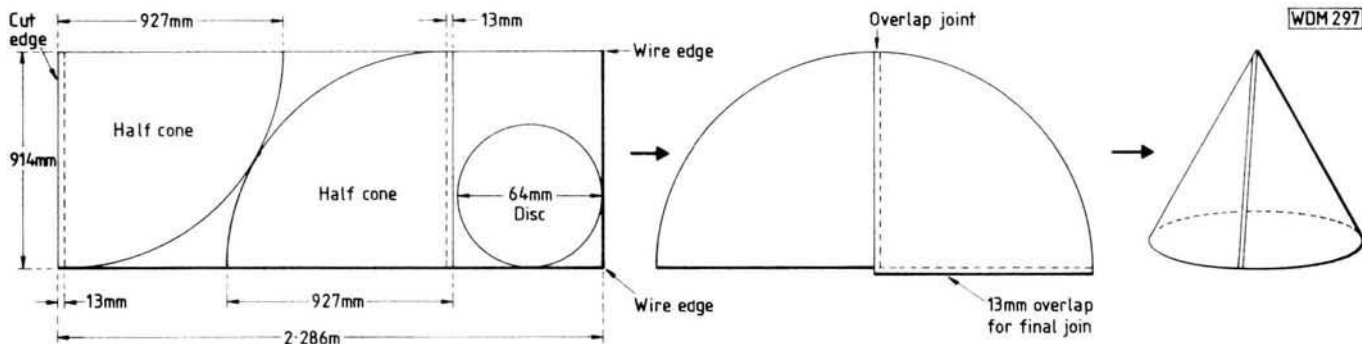
Cut five 150mm lengths of 16 s.w.g. tinned copper wire, and solder four of them, one to each corner of a four-hole fixing SO239 socket, as shown in Fig. 2. Then bend the four wires out to form a four-sided 60° skeleton pyramid and solder the fifth piece of wire on to the centre connection of the socket. Next take the pyramid-shaped socket assembly and insert it into the apex of the wire mesh cone, then solder the wire mesh to the four lengths of tinned copper wire. Finally form the open ends of the wire mesh neatly around

the back of the socket, making sure that none of them shorts to the centre conductor.

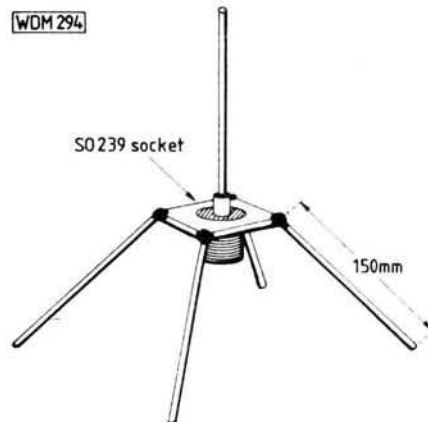
Having completed the cone assembly, now construct the disc. The disc consists of a 250mm diameter circle of tin plated steel, the top of an old biscuit tin, soldered to the underside of a 642mm dia. circle of wire mesh. The wire mesh need only be soldered around the edge of the tin plated steel disc. Next drill a 4mm dia hole in the centre of the disc assembly and then solder over the hole the brass insert from a 5 amp "chocblock" terminal strip (Fig. 3). This will provide fixing and distance adjustment between the disc and cone assemblies.

Assembly and Installation

Place the centre of the completed disc over the vertical wire of the cone assembly, leaving a 12mm gap between the disc and cone. Tighten up the two screws in the connector insert and there you have it, a completed chicken-wire discone.



▲ Fig. 1: Cutting and assembling the wire mesh



◀ Fig. 2: Connection pattern for SO239 socket

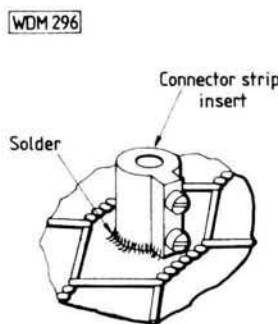
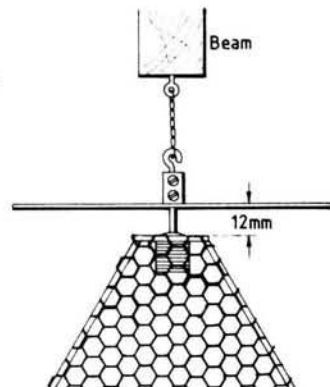


Fig. 3: Final assembly of discone antenna showing connector block installation ▶



- [54] **TUNABLE DISCONE ANTENNA**
[75] **Inventor:** Theodore S. Rappaport, Blacksburg, Va.
[73] **Assignee:** Purdue Research Foundation, West Lafayette, Ind.
[21] **Appl. No.:** 191,055
[22] **Filed:** May 6, 1988
[51] **Int. Cl.⁴** H01Q 1/36; H01Q 13/00
[52] **U.S. Cl.** 343/790; 343/773;
343/830; 343/846; 343/861
[58] **Field of Search** 343/846, 773-775,
343/794, 830, 829, 790, 791, 860, 861
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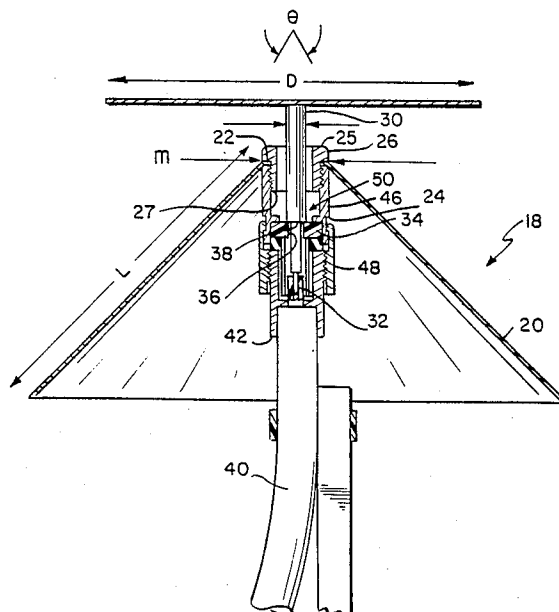
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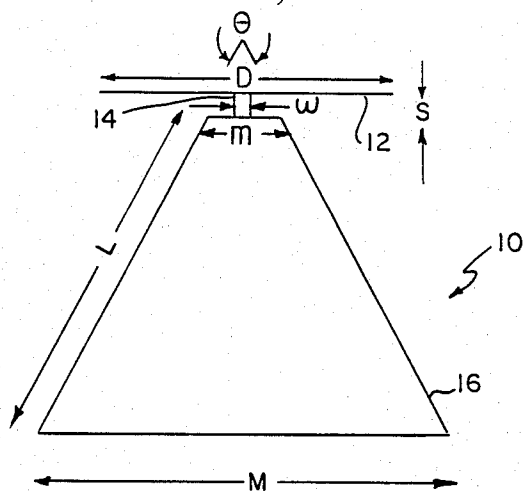
Primary Examiner—Rolf Hille
Assistant Examiner—Michael C. Wimer
Attorney, Agent, or Firm—Barnes & Thornburg

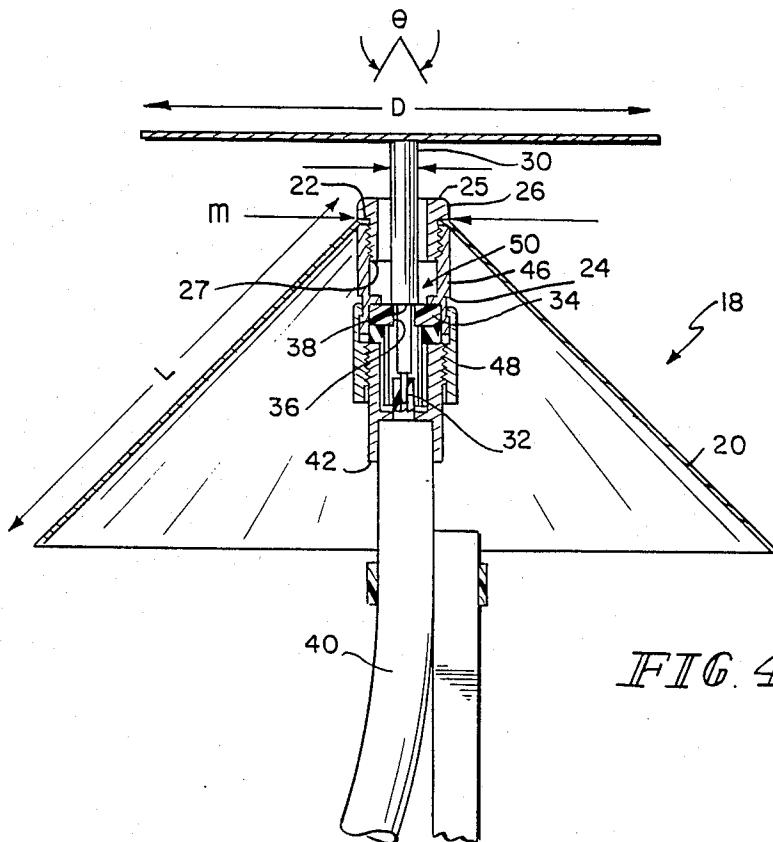
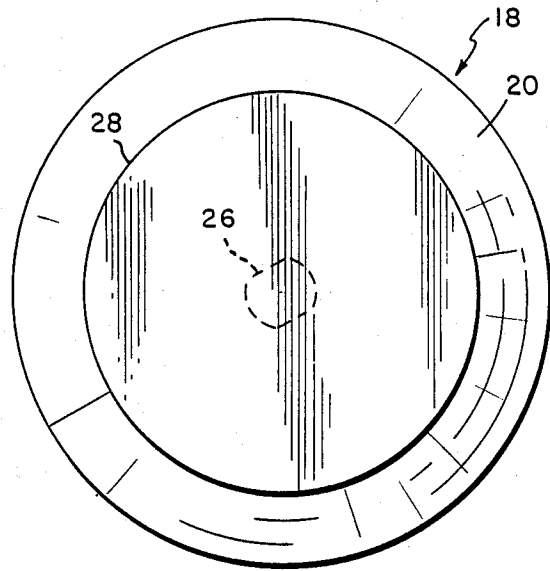
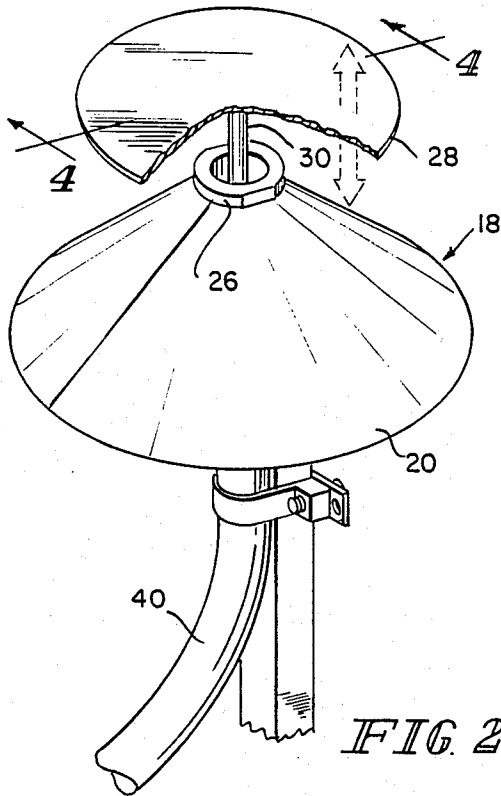
[57] **ABSTRACT**

A discone antenna has a conducting cone having an apex and a conducting disc with a disc feed conductor extending from its center. The conducting disc is mounted at the apex of the cone in spaced relation therewith such that the disc feed conductor extends down into the cone through the cone's apex. A coaxial connector is mounted within the cone at the apex of the cone and defines a tuning cavity therein. A tuning slug is received in the tuning cavity through the apex of the cone and is vertically adjustable within the tuning cavity to tune the antenna.

14 Claims, 3 Drawing Sheets







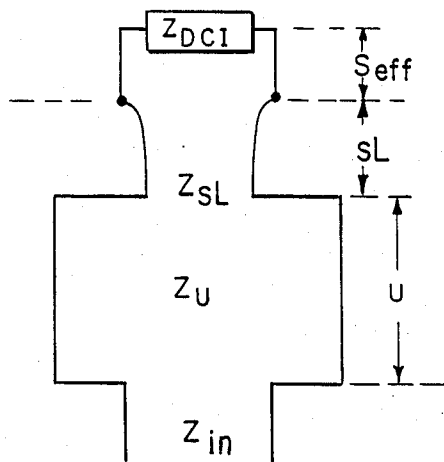


FIG. 6a

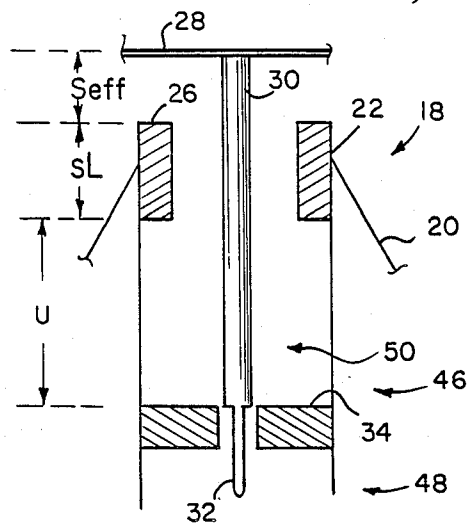


FIG. 6b

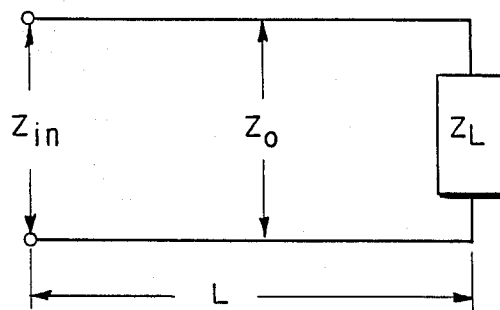


FIG. 7

TUNABLE DISCONE ANTENNA

This invention was funded in part by a grant from the National Science Foundation. The government may have rights in this invention.

This invention relates to antennas and particularly to disccone antennas.

A well known type of antenna is the disccone antenna. The disccone antenna is a broadband antenna and is relatively simple to construct. Its main virtue is that it provides a low voltage standing wave ratio (VSWR) over a bandwidth of several octaves. The disccone antenna, as the name implies, comprises a combination of a disk and a cone and is typically fed by a coaxial feed line. The disk is mounted at the apex of the cone and is connected to the center conductor of the coaxial feed line. The disk is insulated from the cone. The outer conductor of the coaxial feed line is connected to the cone generally at the apex of the cone.

There are known design equations for disccone antennas. These equations were developed empirically using the VHF frequency bands which are below the UHF and microwave frequency bands. The critical design parameters of these equations are considered to be to be the disk-to-cone spacing (s), the diameter of the disk (D), and the slant height of the cone (L). Where the minimum cone diameter (m) is small with respect to the high-pass cutoff frequency of the antenna, as is the case for VHF, s is usually assumed to be much less than D and the useful design formulas have been found to be:

$$s = 0.3 m$$

$$D = 0.7M$$

regardless of the cone flare angle θ , where L is slightly larger than $\lambda/4$ at cutoff. [J. J. Nail, "Designing Disccone Antennas," *Electronics*, pp. 167-169 (August, 1953)]

However, at UHF and microwave frequencies, the effect of certain parameters, such as the diameter of the disc feed conductor, which have negligible effect on the performance of the antenna at lower frequencies now becomes appreciable. This is due to the fact that the magnitude of these parameters at frequencies much lower than microwave frequencies is much less than the wavelengths the antenna receives or transmits. For example, at frequencies much lower than microwave frequencies, i.e., VHF, the diameter of the disc feed conductor is much less than the wavelength of the frequencies which the antenna transmits or receives. However, at higher frequencies such as UHF and microwave frequencies, this relationship no longer holds. Thus, the performance of the disccone antenna becomes much more sensitive to variations in such parameters which at lower frequencies would have negligible effect on the performance of the disccone antenna. Thus, it becomes much more important to be able to tune the disccone antenna to achieve optimum performance by adjusting one or more parameters.

It is an object of this invention to provide a disccone antenna which provides optimal performance at microwave frequencies.

It is another object of this invention to provide a disccone antenna for use with microwave frequencies which can be easily tuned to achieve optimal performance.

It is another object of this invention to provide a disccone antenna which can be constructed simply and inexpensively.

It is another object of this invention to provide a simple and inexpensive wide bandwidth antenna.

A disccone antenna constructed according to this invention has a conducting cone having an apex and a conducting disc having a disc feed conductor extending from its center. The conducting disc is mounted in spaced relation to the apex of the cone such that the conducting disc's disc feed conductor extends down into the cone through the cone's apex. A tuning cavity defining member is coupled to the cone and defines a tuning cavity about the conducting disc's disc feed conductor at the apex of the cone. A tuning slug is received in the tuning cavity and is vertically adjustable therein to tune the disccone antenna. The tuning cavity defining member can be a coaxial connector mounted at an upper end to the cone at the apex of the cone wherein the coaxial connector defines the tuning cavity therein. The disccone antenna can be fed by a coaxial feed line which is coupled to the coaxial connector.

Additional features and advantages of the invention will become apparent to those skilled in the art upon consideration of the following detailed description of a preferred embodiment, exemplifying the best mode of carrying out the invention as presently perceived. The detailed description particularly refers to the accompanying figures in which:

FIG. 1 is a schematic of a prior art disccone antenna; FIG. 2 is a perspective view of a disccone antenna constructed in accordance with this invention;

FIG. 3 is a top view of the disccone antenna of FIG. 2;

FIG. 4 is a sectional view of the disccone antenna of FIG. 2 taken along the line 4-4;

FIG. 5 is a schematic representation of a disccone antenna constructed according to this invention showing in more detail the interface between the conducting disc conducting cone, and tuning slug;

FIGS. 6a-6b are a schematic of an impedance model for a disccone antenna constructed in accordance with the invention and a schematic of a disccone antenna constructed in accordance with the invention; and

FIG. 7 is a schematic of a transmission line terminated with a complex load.

Referring to FIG. 1, a prior art disccone antenna 10 has a conducting disk 12 with a center conductor or disc feed conductor 14 extending from its center and a conducting cone 16. The conducting disk 12 is mounted generally at the apex of the cone 16 in spaced relation to the apex of the cone 16 and is insulated from the cone 16. The disk feed conductor of the conducting disk extends down into the cone and mates with a feed line (not shown). Disccone antenna 10 can be characterized by the dimensions D , L , M , m , θ , s and w , where D is the diameter of the conducting disk 12, L is the slant height of the cone 16, M is the maximum cone diameter, m is the minimum cone diameter (diameter of the cone at its apex), θ is the flare angle of the cone 16, s is the spacing between disk 12 and cone 16, and w is the diameter of the disc feed conductor 14.

Disccone antenna 10 can further be characterized by the following design equations:

$$s = 0.3 m;$$

$$D = 0.7M;$$

where it is assumed that $s < \lambda/4$, $m \approx \lambda/75$ at high-pass cutoff, L is slightly larger than $\lambda/4$ at high-pass cutoff, and w is not considered. In these prior art design equations w is not considered because it is much less than λ_c (high-pass cutoff) and thus has a negligible effect on the performance of the antenna.

Referring to FIGS. 2-4, a discone antenna 18 constructed in accordance to this invention is shown. Discone antenna 18 has a conducting cone 20 which has an apex 22. A tuning cavity defining member, which is illustratively a coaxial connector 24, is mounted inside cone 20 at the apex 22 of cone 20. Illustratively, coaxial connector 24 is a UG-21d/U male coaxial connector. Coaxial connector 24 is illustratively mounted to the apex 22 of cone 20 by having one end affixed to the apex 22 of cone 20. Coaxial connector 24 provides the RF feed connection for discone antenna 18 and also provides mechanical support for discone antenna 18.

Coaxial connector 24 has an upper portion or throat 46 which defines a tuning cavity 50 and a lower portion or connector head 48. Connector head 48 has a core of dielectric material 34 with a hole 36 extending through the center thereof. The upper end of throat 46 is threaded to threadably receive a tuning slug 26 which is illustratively a cable clamp nut. Tuning slug 26 has an upper portion 25 which extends axially upwards from the apex 22 of cone 20 toward conducting disc 28 and a lower portion 27 which penetrates into tuning cavity 50. Tuning slug 26 is used to tune discone antenna 18 as will be discussed in more detail below.

Discone antenna 18 also includes a conducting disc 28. A disc feed conductor 30 extends from the center of conducting disc 28. A pin 32 extends from a distal end of disc feed conductor 30 of conducting disc 28. The junction of pin 32 and disc feed conductor 30 forms an annular shoulder 38. Conducting disc 28 is mounted at the apex 22 of cone 20 in spaced relation therewith such that the disc feed conductor 30 extends down into cone 20 with the pin 32 extending through the hole 36 in the connector head 48 of coaxial connector 24. Pin 32 illustratively provides the center pin for coaxial connector 24.

Discone antenna 18 is connected to an RF feed source (not shown) or to an RF receiver (not shown) by a coaxial feed line 40. Illustratively, a female coaxial connector 42 is affixed to the end of coaxial feed line 40 and mates with the connector head 48 of coaxial connector 24.

Illustratively, conducting disc 28 is held in spaced relation to the apex 22 of cone 20 by female coaxial connector 42 holding up pin 32 of disc feed conductor 30 such that conducting disc 28 is held in spaced relation to the apex 22 of cone 20. Conducting disc 28 could also be held in spaced relation to the apex 22 of cone 20 by the annular shoulder 38 of disc feed conductor 30 resting against dielectric core 34 of connector head 48 of coaxial connector 24. It should be understood that conducting disc 28 can be mounted to cone 20 in a variety of ways provided that conducting disc 28 is held in spaced relation to the apex 22 of cone 20 and is electrically insulated from cone 20.

Tuning slug 26 is used to tune discone antenna 18. The amount by which tuning slug 26 is threaded into coaxial connector 24 is adjusted to optimize the performance of discone antenna 18 by minimizing the VSWR. As discussed in more detail below, adjusting the distance tuning slug 26 is screwed into coaxial connector 24 effectively adjusts the spacing between conducting

disc 28 and the cone 20 by adjusting the distance between the top of tuning slug 26 and conducting disc 28 and also adjusts the impedance of tuning cavity 50.

FIG. 5 is a schematic representation of discone antenna 18 of FIGS. 2-4 showing particularly the relationship of coaxial connector 24, conducting disc 28 and tuning slug 26 at the apex 22 of cone 20. Discone antenna 18 is characterized here by the same dimensions used to characterize discone antenna 10 of FIG. 1 wherein the diameter of tuning cavity 50 is illustratively equal to m (the minimum cone diameter). Additionally, discone antenna 18 is further characterized by the dimensions s_{eff} , sL , I , U , B and T , where s_{eff} is the distance between the top of the tuning slug 26 and the conducting disc 28, sL is the length of the tuning slug 26, T is the wall thickness of tuning slug 26, I is the depth tuning slug 26 penetrates into tuning cavity 50 (the "tuned" portion of tuning cavity 50), U is the distance between the bottom of tuning slug 26 and the bottom of tuning cavity 50 (the "untuned" portion of tuning cavity 50), and B is the length of the tuning cavity 50.

Discone antenna 18 is tuned by adjusting the depth tuning slug 26 penetrates into tuning cavity 50, i.e., adjusting dimension I , to optimize (minimize) VSWR. Adjusting dimension I in turn adjusts s_{eff} and U . Adjusting the depth that tuning slug 26 penetrates tuning cavity 50 alters the input impedance of discone antenna 18 by a three section tapered transmission line as explained in more detail below.

Where μ is permeability, μ_o is the permeability of free space, ϵ is permittivity, ϵ_o is the permittivity of free space, and ϵ_r is relative permittivity or the dielectric constant, the characteristic impedance of a dielectric cable is given by:

$$(1/2\pi)(\sqrt{\mu/\epsilon})(\log_e(b/a)) \quad (1)$$

where $\mu = \mu_o$ ($\mu_o = 4\pi \times 10^{-7}$ henrys/meter), $\epsilon = \epsilon_r \epsilon_o$; $\epsilon_o = (1/36\pi) \times 10^{-9}$ farads/meter, and a/b is the ratio of the diameter of the inner conductor to the inside diameter of the outer conductor. The dielectric coefficient or permittivity, ϵ_r , is equal to one for air. For other materials, ϵ_r may be different than one.

In discone antenna 18, tuning occurs in the tuning cavity 50, i.e., in the connector throat 46 of coaxial connector 24, and at the interface between conducting disc 28 and the top of tuning slug 26. In the connector head 48 of coaxial connector 24, the geometric relationships between the center pin 32 and the dimension M are selected in known fashion to provide a suitable impedance match.

The impedance seen due to tuning cavity 50 and the disc 28/cone 20 interface can be modeled as a tapered three section tunable transmission line. FIG. 6a is a schematic of such a tapered three section tunable transmission line and FIG. 6b is schematic of discone antenna 18. FIGS. 6a and 6b are drawn side-by-side to show the correspondence between the elements of the impedance model of FIG. 6a and the physical elements of discone antenna 18 shown schematically in FIG. 6b. Referring to FIGS. 5 and 6, the disc 28/cone 20 interface offers a complex impedance Z_{DCI} . The tuning slug 26 forms a short transmission line segment having a characteristic impedance Z_{sL} given by equation 1 above where a is the diameter of disc feed conductor 30, (w), and b is the inside diameter of tuning slug 26, ($m - 2T$). The untuned portion of the tuning cavity (dimension U) has a characteristic impedance Z_U , also given by Equation 1 where

a is again the diameter of disc feed conductor 30, (w), but b is the diameter of tuning cavity 50, (m).

It is well known that altering the length of a transmission line terminated with a complex load affects the input impedance to that transmission line. FIG. 7 is a schematic of a transmission line terminated with a complex load. Referring to FIG. 7, the input impedance of a transmission line terminated with a complex load is given by:

$$Z_{in} = Z_o \left[\frac{Z_L + jZ_o[\tan(2\pi/\lambda)]L}{Z_o + jZ_L[\tan(2\pi/\lambda)]L} \right] \quad (2)$$

where Z_{in} is the input impedance, Z_o is the characteristic impedance of the transmission line, L is the length of the transmission line, and Z_L is the complex load impedance. Therefore, by physically adjusting the depth tuning slug 26 penetrates into tuning cavity 50 of disccone antenna 18 (adjusting dimension I), the physical and electrical lengths of the tunable transmission lines, i.e., Z_U and Z_{DCI} are altered. Z_{DCI} changes due to the change in the dimension S_{eff} and Z_U changes due to the change in the dimension U. Z_{sL} remains the same because the length of the tuning slug does not change.

The above discussion applies when changing I does not change in any way the impedance of the transmission line formed by turning slug 26, i.e., the characteristic impedance of the tuning slug transmission line remains the same over the length of the tuning slug such as is the case when there is air between the tuning slug 26 and disc feed conductor 30. However, if the characteristic impedance of the tuning slug transmission line changes at any point along its length due to changes in I, the above model will change. For example, in an embodiment of the invention, tuning cavity 50 could have a core of dielectric material concentrically extending along its length such that at least a portion of this core is disposed between tuning slug 26 and disc feed conductor 30. The impedance model would then change to a tapered four section tunable transmission line. One section would be the untuned portion of tuning cavity 50 (dimension U); a second section would be the tuned portion of tuning cavity 50 (dimension I); the third section would be the distance between the top of tuning cavity 50 (apex 22 of cone 20) where the core of dielectric material would end and the top of tuning slug 26 ($sL - I$); and the fourth section would be Z_{DCI} .

This discussion demonstrates that there are several important geometrical relationships in disccone antenna 18 which must be taken into account to optimize the performance of disccone antenna 18, i.e., minimizing VSWR. Applicant has found that these relationships, discussed below, are important for frequency bands where the dimension m is greater than one-twentieth of the wavelength of the lowest operating frequency (high-pass cut-off frequency) for which the disccone antenna 18 is to be used.

Applicant has found that for a disccone antenna (using the nomenclature set forth above) having a tuning cavity of diameter m (which, illustratively, is also the minimum cone diameter), a tuning cavity depth B, an antenna flare angle of θ , a desired input impedance of Z_{in} , a tuning slug thickness T, and a high-pass cut-off frequency f_c having a wavelength μ_c , an optimum impedance match, i.e., best or lowest VSWR, is obtained when:

$$45^\circ \leq \theta \leq 75^\circ \quad (3)$$

$$sL \leq 0.75B; sL \geq T \quad (4)$$

$$T \leq m/2 \quad (5)$$

$$m > \lambda_c/20 \quad (6)$$

$$s = 0.5 m \quad (7)$$

$$L = 1.15 \lambda_c/4 \quad (8)$$

$$M = 2L(\tan(\theta/2)) + m \quad (9)$$

$$D = 0.80 M \{1 - [(\theta - 60^\circ)/60^\circ](4T/m)\} \quad (10)$$

$$I = sL - T \quad (11)$$

$$w = 0.77 m(e^{-[Z_{in} \times 2\pi \sqrt{\epsilon/\mu}]} \times \{1 - (sL/B)[I/(B - D)] \ln[m/(m - 2T)]\}) \quad (12)$$

$$s_{eff} = T \quad (13)$$

In designing a disccone antenna, the designer would illustratively choose Z_{in} , f_c , m, B, θ , T, sL and then design the disccone antenna to satisfy the above relationships. Further, by setting sL and T equal to zero, the above equations will define the optimum design for a disccone antenna without a tuning slug.

The above equations were derived empirically from tests conducted in the 1 to 2 GHz range. They define the optimum design for a disccone antenna for use with frequencies in the UHF and microwave range. At lower frequencies, i.e., HF or VHF, large coaxial connectors would be required.

Although the invention has been described in detail with reference to certain preferred embodiments and specific examples, variations and modifications exist within the scope and spirit of the invention as described and as defined in the following claims.

What is claimed is:

1. A disccone antenna for use at UHF and microwave frequencies, comprising:

- (a) a conducting cone having an apex;
- (b) a conducting disc having a disc feed conductor extending from its center;
- (c) means for mounting the conducting disc in spaced relation to the apex of the cone such that the conducting disc's disc feed conductor extends down into the cone through the cone's apex;
- (d) a tuning cavity defining member coupled to the cone and defining a tuning cavity about the conducting disc's disc feed conductor at the apex of the cone; and
- (e) a tuning slug having a lower portion received in the tuning cavity and an upper portion extending upwardly from the apex of the cone toward the conducting disc, the tuning cavity and the tuning slug and the conducting disc forming a tapered transmission line having a plurality of segments, each segment having an impedance, the tuning slug adjustably received in the tuning cavity to permit the depth the tuning slug penetrates into the tuning cavity to be adjusted to vary the impedance of at least two of the transmission line segments to tune the antenna where tuning of the antenna is accomplished principally by the adjustment of the tuning slug.

2. The discone antenna of claim 1 wherein the tuning cavity defining member comprises a coaxial connector to which a feed line is coupled, the coaxial connector having an upper end mounted to the cone at the apex of the cone, the coaxial connector defining the tuning cavity therein, and means for coupling the conducting disc's disc feed conductor to the coaxial connector.

3. The discone antenna of claim 2 wherein the coaxial connector has an upper throat portion which defines the tuning cavity and a lower connector head portion to which the feed line is coupled, the upper throat portion having a threaded inner surface, the tuning slug comprising a cylindrical tuning slug having a threaded outer surface, the tuning slug threadably received in the tuning cavity to permit the depth the tuning slug penetrates into the tuning cavity to be adjusted by screwing the tuning slug into and out of the tuning cavity.

4. The discone antenna of claim 3 wherein the means for coupling the conducting disc's disc feed conductor to the coaxial connector comprises the disc feed conductor having a connector pin extending from a distal end which extends into the connector head portion to be a center pin of the coaxial connector.

5. A discone antenna for use at UHF and microwave frequencies, comprising:

- (a) a conducting cone having an apex;
- (b) a conducting disc having a disc feed conductor extending from its center;
- (c) means for mounting the conducting disc in spaced relation to the apex of the cone such that the conducting disc's disc feed conductor extends down into the cone through the cone's apex;
- (d) a tuning cavity defining member coupled to the cone and defining a tuning cavity about the conducting disc's disc feed conductor at the apex of the cone; and
- (e) a tuning slug having a lower portion received in the tuning cavity and an upper portion extending upwardly from the apex of the cone toward the conducting disc, the tuning slug adjustably received in the tuning cavity to permit the depth the tuning slug penetrates into the tuning cavity to be adjusted to vary the impedance of the tuning cavity and the effective distance between the apex of the cone and the conducting disc to tune the antenna where tuning of the antenna is accomplished principally by adjustment of the tuning slug, the effective distance between the apex of the cone and the conducting disc comprising the distance between a top of the tuning slug and the conducting disc.

6. The discone antenna of claim 5 wherein the tuning slug is threadably and adjustably received in the cone at the apex of the cone.

7. The discone antenna of claim 5 and further including a coaxial connector for coupling the antenna to a feed line, the coaxial connector having an upper end mounted within the cone to the cone at the apex of the cone, the coaxial connector defining the tuning cavity and having a threaded inner surface for threadably receiving the tuning slug, the tuning slug being screwed into and out of the tuning cavity to vary the impedance of the tuning cavity and the effective distance between the apex of the cone and the conducting disc.

8. A discone antenna for use at UHF and microwave frequencies, comprising:

- (a) a conducting cone having an apex;
- (b) a conducting disc having a disc feed conductor extending from its center;

(c) means for mounting the conducting disc in spaced relation to the apex of the cone such that the conducting disc's disc feed conductor extends down into the cone through the cone's apex;

(d) a feed connector having an upper end mounted to an inner surface of the cone at the apex of the cone, the feed connector extending concentrically axially downward from the apex of the cone, the feed connector defining a tuning cavity therein about the conducting disc's disc feed conductor; and

(e) a tuning slug adjustably received in the tuning cavity for vertical adjustment therein having a lower portion received in the feed connector and an upper portion extending upwardly from the apex of the cone toward the conducting disc, the distance between a top of the tuning slug and the conducting disc comprising an effective distance between the apex of the cone and the conducting disc, the tuning cavity and tuning slug and conducting disc comprising a tapered transmission line having a plurality of segments, each segment having an impedance, one segment comprising the effective distance between the apex of the cone and the conducting disc, the tuning slug adjustably received in the feed connector to permit the depth the tuning slug penetrates into the tuning cavity defined by the feed connector to be adjusted to vary the impedance of the transmission line segment which is the effective distance between the apex of the cone and the conducting disc and to vary the impedance of at least one other transmission line segment within the tuning cavity to vary the impedance of the tuning cavity to tune the antenna where tuning of the antenna is accomplished principally by adjusting the tuning slug.

9. The discone antenna of claim 8 wherein the feed connector has a threaded inner surface and the tuning slug has a threaded outer surface, the tuning slug threadably received in the feed connector for vertical adjustment therein by screwing the tuning slug into and out of the feed connector.

10. The discone antenna of claim 9 wherein the feed connector comprises a coaxial connector having an upper throat portion and a lower connector head portion, the upper throat portion defining the tuning cavity and having the threaded inner surface for threadably receiving the threaded tuning slug, the conducting disc's disc feed conductor having a connector pin at a distal end which extends into the connector head portion of the coaxial connector to act as a center pin of the coaxial connector.

11. A discone antenna for use at UHF and microwave frequencies, comprising:

- (a) a conducting cone having an apex;
- (b) a conducting disc having a disc feed conductor extending from its center;
- (c) means for mounting the conducting disc in spaced relation to the apex of the cone such that the conducting disc's disc feed conductor extends down into the cone through the cone's apex;
- (d) a tuning cavity defining member coupled to the cone and defining a tuning cavity about the conducting disc's disc feed conductor at the apex of the cone;
- (e) a tuning slug having a cylindrical passage extending longitudinally therethrough, the tuning slug received in the tuning cavity so that the disc feed

- conductor passes through the tuning slug's passageway; and
 (f) the discone antenna further defined by the following relationships:

$$45^\circ \leq \theta \leq 75^\circ;$$

$$sL \leq 0.75B; sL \geq T;$$

$$T \leq m/2;$$

$$m > \lambda_c/20;$$

$$s = 0.5 m;$$

$$L = 1.15 \lambda_c/4;$$

$$M = 2L(\tan(\theta/2)) + m;$$

$$D = 0.80 M \{1 - [(\theta - 60^\circ)/60^\circ](4T/m)\};$$

$$I = sL - T;$$

$$w = 0.77 m(e^{-[Z_{in} \times 2\pi \sqrt{\epsilon/\mu}]} \times$$

$$\{1 - (sL/B)[I/(B - D)]\ln[m/(m - 2T)]\};$$

$$s_{eff} = T$$

where θ is the cone flare angle, Z_{in} is the desired input impedance, m is the diameter of the tuning cavity, B is the depth of the tuning cavity, sL is the length of the tuning slug, T is the wall thickness of the tuning slug, λ_c is the high-pass cut-off wavelength, s is the distance from the apex of the cone to the conducting disc, L is the slant height of the cone, M is the maximum diameter of the cone, D is the diameter of the conducting disc, I is the depth the tuning slug penetrates into the tuning cavity, w is the diameter of the conducting disc's disc feed conductor, ϵ is the permittivity and μ is the permeability of the portion of the tuning cavity which the tuning slug penetrates, and s_{eff} is the distance between the top of the tuning slug and the conducting disc.

12. The discone antenna of claim 11 wherein the tuning cavity defining member comprises a coaxial connector having an upper end mounted to the cone at the

apex of the cone, the coaxial connector having an upper throat portion defining the tuning cavity therein and a lower connector heat portion, the tuning slug being threaded and the upper throat portion being threaded to threadably receive the threaded tuning slug to permit the depth the tuning slug penetrates into the tuning cavity to be adjusted by screwing the tuning slug into and out of the tuning cavity to tune the antenna.

13. A discone antenna for use at UHF and microwave frequencies, comprising:

- (a) a conducting cone having an apex;
- (b) a conducting disc having a disc feed conductor extending from its center;

(c) means for mounting the conducting disc in spaced relation to the apex of the cone such that the conducting disc's disc feed conductor extends down into the cone through the cone's apex;

(d) a feed connector coupled to the cone and defining a cavity about the conducting disc's disc feed conductor at the apex of the cone; and

(e) the discone antenna further defined by the following relationships:

$$45^\circ \leq \theta \leq 75^\circ;$$

$$m > \lambda_c/20;$$

$$s = 0.5 m;$$

$$L = 1.15 \lambda_c/4;$$

$$M = 2L[\tan(\theta/2)] + m;$$

$$D = 0.80M;$$

$$w = 0.77 m(e^{-[Z_{in} \times 2\pi \sqrt{\epsilon/\mu}]} \times$$

where θ is the cone flare angle, Z_{in} is the desired input impedance, m is the minimum diameter of the cone, λ_c is the high-pass cut-off wavelength, s is the distance from the apex of the cone to the conducting disc, L is the slant height of the cone, M is the maximum diameter of the cone, D is the diameter of the conducting disc, w is the diameter of the conducting disc's disc feed conductor, ϵ is the permittivity and μ is the permeability of the cavity.

14. The discone antenna of claim 13 wherein the feed connector comprises a coaxial connector having an upper end mounted to the cone at the apex of the cone.

* * * * *

The Discone: A Wideband Omnidirectional Antenna

"The discone and its variants are the most commonly used low-gain wide-band base-station antennas." This quotation comes from possibly the most comprehensive antenna engineering manual ever written.¹ So, if you've never tried a discone antenna, such a statement in such an impressive manual might just make you wonder what you're missing!

First, don't let the term "low-gain" scare you off. "Low-gain" means that the discone has somewhat less gain than our standard-of-reference, the half-wave dipole. However, the discone has gain comparable to the respected and popular groundplane antenna.

And, also like the groundplane, the discone has a nondirectional response to signals in the horizontal plane. Thus it gives good all-around coverage so desirable at a base station.

Why would we choose the discone over a groundplane antenna at times?

Well, whereas the groundplane is a resonant one-band antenna in its basic design, the construction of the discone gives it one of the widest bandwidths of any antenna: up to a 10 to 1 frequency spread. This means that a discone can be designed to cover a chunk of RF spectrum such as 100 MHz to 1000 MHz. We're talking real bandwidth here!

So, if you want a base-station antenna with good all-around coverage and a super bandwidth, maybe you should consider building this month's antenna: a discone designed to cover from just above the FM broadcast band (110 MHz) well on up into the UHF band.

Just how high in frequency this antenna will function effectively depends on the care you use in making it. I suspect that most readers will be able to construct this antenna to function to at least 500 MHz, and possibly higher.

For the hams among us, that means that it should also give good service on the 2 meter, 220 MHz, and 440 MHz ham bands.

Let's make a super-wide-band antenna ...

To construct this antenna, we need a ten foot length of three foot wide, small mesh (1/2 inch mesh or smaller) hardware cloth. Hardware cloth is a type of screening wire, and yes, you get it at the hardware store! You also need a tin can lid three or more inches in diameter (make sure it is bright tin, so that you can easily solder to it), and an SO-239 coaxial cable female socket.

To begin, lay out and cut the parts of the antenna from the hardware cloth as shown in Figure 1. Be prepared to use patience on this job, it is tedious. A magic marker on a length of string makes a good compass for drawing the curves.

Next, join the small piece-of-pie-shaped wedge to the half-circle piece to make the completed cone-piece as shown in Figure 1. The cut wire ends of the hardware cloth are sharp, and the help of a friend to handle the wire would be nice.

The overlapped junction of the two pieces overlaps two inches. You may bolt, tie, or solder these pieces together, as the electrical conductivity important to the cone is down the cone, not across it.

Next, shape the completed cone-piece

into a cone shape. Overlap the joining edges two inches and then bolt, tie, or solder this joint together permanently.

You are now ready to mount the coax socket in the tip of the cone. Cut the tip of the cone off so that the flange of the socket just fits snugly inside and can be soldered in place. Mount this connector with its threaded portion downward into the cone, and the axis of the connector-body vertical.

The connection between the socket-skirt and the cone-tip should be soldered well at as many places around the connector skirt as possible.

Now take the tin-can lid and put a small hole in its center. Make the hole so that the center-connector of the socket fits snugly in it. Solder up (fill with solder) the hole in the lid, and "tin" the coax center-connector (cover it with solder preparatory to mounting the disc on it).

This gets these two parts ready for soldering them together. Solder the lid in place, being careful that it is in a horizontal position.

Take care to make the height of the disc above the cone tip (socket base) correct. I know we can't judge .44 inch accurately, but make sure that the height is

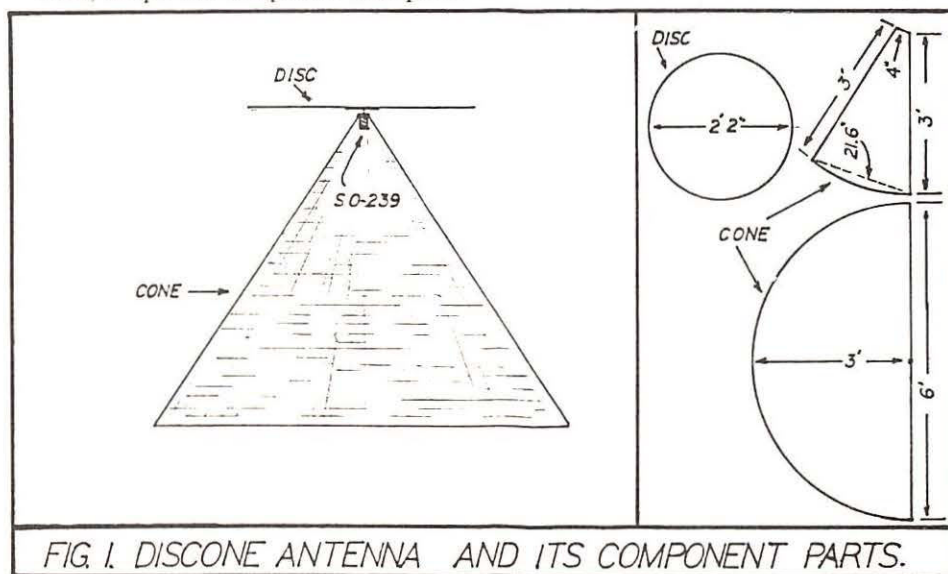


FIG. 1. DISCONE ANTENNA AND ITS COMPONENT PARTS.

just a wee bit less than .5 inch. To get the proper spacing on mine, I had to mount the lid out on the end of the socket center-connector.

Now lay the disc on the lid with the disc-center directly over the hole in the lid. Solder the disc to the lid in as many places as is practical around the edge of the lid. This soldering is for both electrical conductivity and for mechanical strength.

Your antenna is now ready to use!

Using the antenna:

Although you can mount this antenna outside, it will need to be protected from the weather in some way if you do. Mounting it indoors is the preferred mode. It can be put in an attic, crawl-space, or even in your operating room.

An enclosure of fiberglass or box frame covered with sheet plastic should be OK for outdoor mounting. Commercial models are sometimes covered with a fiberglass or plastic dome.

As always, if your building has a lot of metal in its construction, you may find that indoor mounting is not too effective. And the old antenna rule of "the higher the better" should be kept in mind. I used mine sitting on the floor of my second-story operating room with good results, but better results were had with it in the attic.

RADIO RIDDLES

Last month we discussed a rabbit-ear antenna, and then I asked if you had "... ever heard of the 'big ear' antenna? What is it, and who made it famous?"

Well, the "big ear" was the work of John Kraus, who is responsible for so many other antenna designs which we now happily enjoy. The "big ear" was a radiotelescope antenna which Kraus used in much of his early work in radio astronomy.

"The Big Ear"² is also the name of Kraus's autobiography, which makes very interesting reading for anyone interested in the development of radio or

radioastronomy, antennas in particular.

Kraus is also the author of perhaps the most widely-read engineering antenna text published.³ Coincidentally, most of the equations used in designing this month's discone came from this very useful book.

This month's riddle: What is a "volcano smoke" antenna, and how does an antenna get such a name?

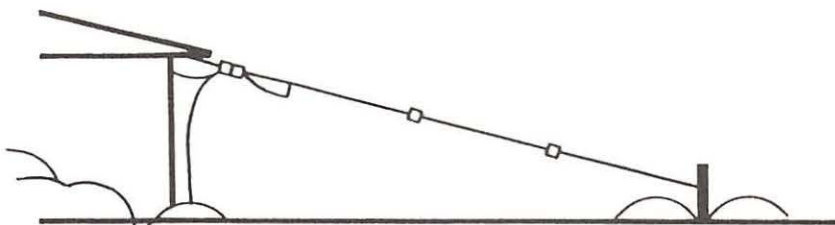
Find the answer to this month's riddle, and much more, next month in your copy of *Monitoring Times*. Till then, Peace, DX, and 73.

mt

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2. *The Big Ear*. John Kraus, Cygnus-Quasar Books, 1976, Powell, Ohio.
3. *Antennas*. John Kraus, 1950, McGraw-Hill Book Company, New York.

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Low Cost Discone Antenna

Wideband coverage from 144 to 1296 MHz.

by Phil Salas AD5X

I needed an antenna that would satisfy a lot of needs. After purchasing an ICOM R-7000 receiver (25–2000 MHz) for some experimental work in the UHF and low microwave ham bands, I wanted a good broadband antenna that I could easily mount in my attic and that would provide coverage of the 144, 220, 450, 903, and 1296 MHz ham bands. I also needed this antenna to provide a good match so that it could be used for transmitting within these ham bands as well. Though this sounds like I'm asking a lot, there is a broadband antenna that can satisfy these needs: the discone antenna.

The Discone Antenna

When properly designed, a discone antenna provides decade (10:1) frequency coverage with a good match (see Figure 1). The discone consists of a disk (the driven element) mounted over a conical ground plane. The cone is an equilateral triangle whose dimensions are a quarter wavelength at the lowest operating frequency. The disk (driven element) has a diameter of 70% of a quarter wavelength at the lowest operating frequency. The disk should be very close to the apex of the cone; the recommended spacing is from 10–30% of the diameter of the apex of the cone.

The trick is to be able to easily realize the cone and disk as well as provide a solid insulated support for the disk and a sound mounting method for the overall antenna. Also, this antenna should be inexpensive, and easily constructed with readily available

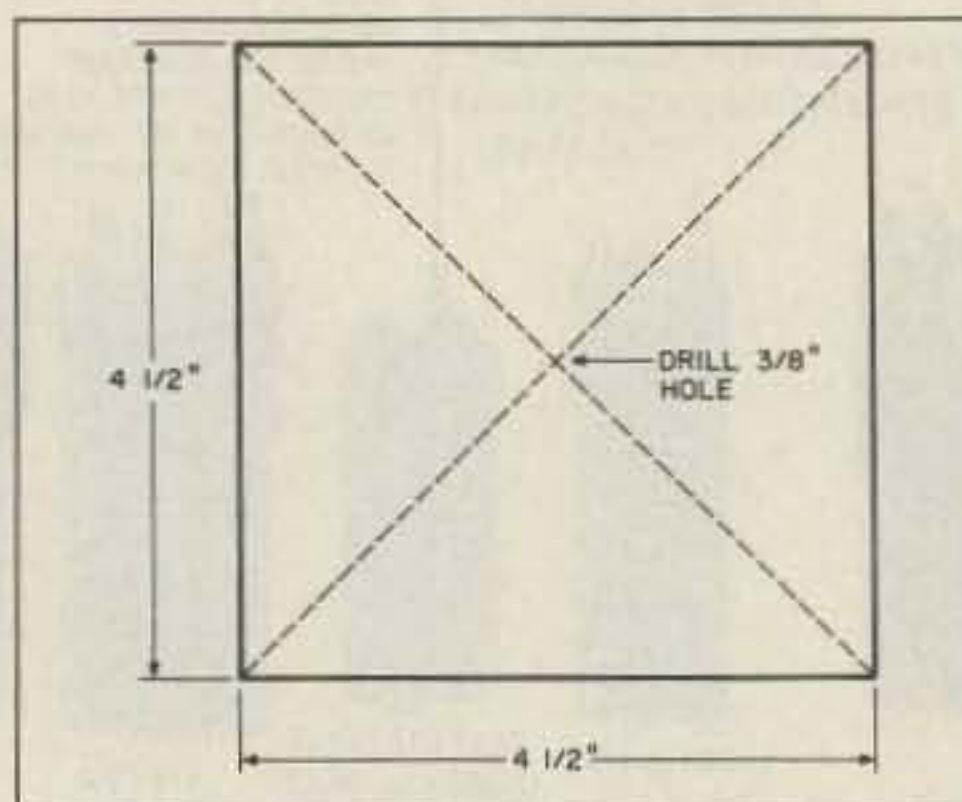


Figure 2. Dimensions of the disk support.

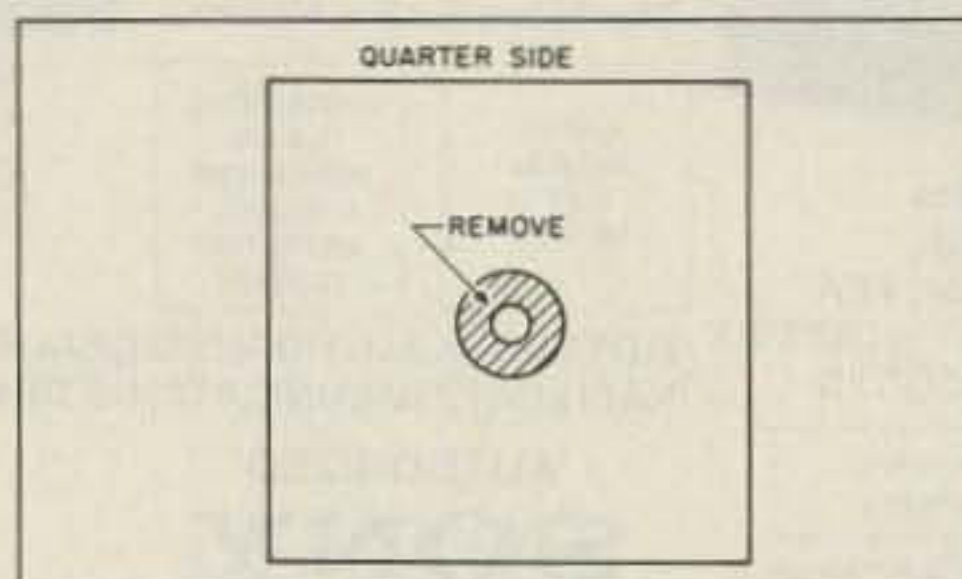


Figure 3. Disk support preparation.

parts from hardware and Radio Shack stores.

Since I wanted to cover the two meter band, I picked the lower frequency limit to be below the lower band edge. The actual frequency I picked was 137 MHz. A decade of coverage should still give me up to 1370 MHz, which suited my needs. The equation for this is: $\frac{1}{4}$ wavelength = $2952/137 = 21.5'' =$ cone side; disk diameter = $0.7 \times 21.5'' = 15''$.

Now all I had to do was figure out how to build it!

Constructing the Discone

See the "Parts List." The last three items came from Radio Shack. The $\frac{3}{8}''$ solder lugs are part of the package (two per package) of solder lugs from Radio Shack, but you can save money if you can find $\frac{3}{8}''$ solder lugs separately. I bought all of the other items in the electrical department of a local hardware store.

Now, let's get to work. We will first prepare all the individual pieces.

The disk support will be made out of the

single-sided printed circuit board. First, cut this board into a $4\frac{1}{2}'' \times 4\frac{1}{2}''$ square. With a pencil, draw diagonal lines from corner to corner on one side. See Figure 2. Drill a $\frac{3}{8}''$ diameter hole at the intersection of the lines (the center of the PC board). Referring to Figure 3, center a quarter over the hole on the foil side of the PC board and trace around its circumference. Using a sharp X-ACTO™ knife, cut through the copper on the circular lines just traced. Now remove the copper within the circle. A soldering gun will aid in removing the copper foil.

The light fixture canopy needs some modification. These kits include a fixture for mounting a lamp on, a short length of 1/8IP threaded steel lamp pipe, and some additional hardware. Refer to Figure 4. Nibble or cut a slot along one side of the canopy at least $0.3'' \times 0.3''$. This will pass the coaxial cable when the canopy and antenna are mounted.

Cut all eight welding rods to a length of 21.5''. Unless you have heavy cutters, you will need to use a hacksaw. Remove any insulation from the $\frac{3}{8}''$ solder lugs, insert only one end of the cut welding rods into the solder lug crimp end, crimp the lug and solder. See Figure 5.

Cut the remaining eight short pieces of welding rods to $7\frac{1}{4}''$. Finally, determine the center of the 4'' round plastic electrical box cover and drill a $\frac{3}{8}''$ hole. It is important that this hole be well-centered, so take care in determining this location.

Now take the 30'' 1/8IP all-thread steel lamp pipe and carefully tin one end of the pipe. See Figure 6. Be careful not to get solder on the threads of the pipe. This pipe is

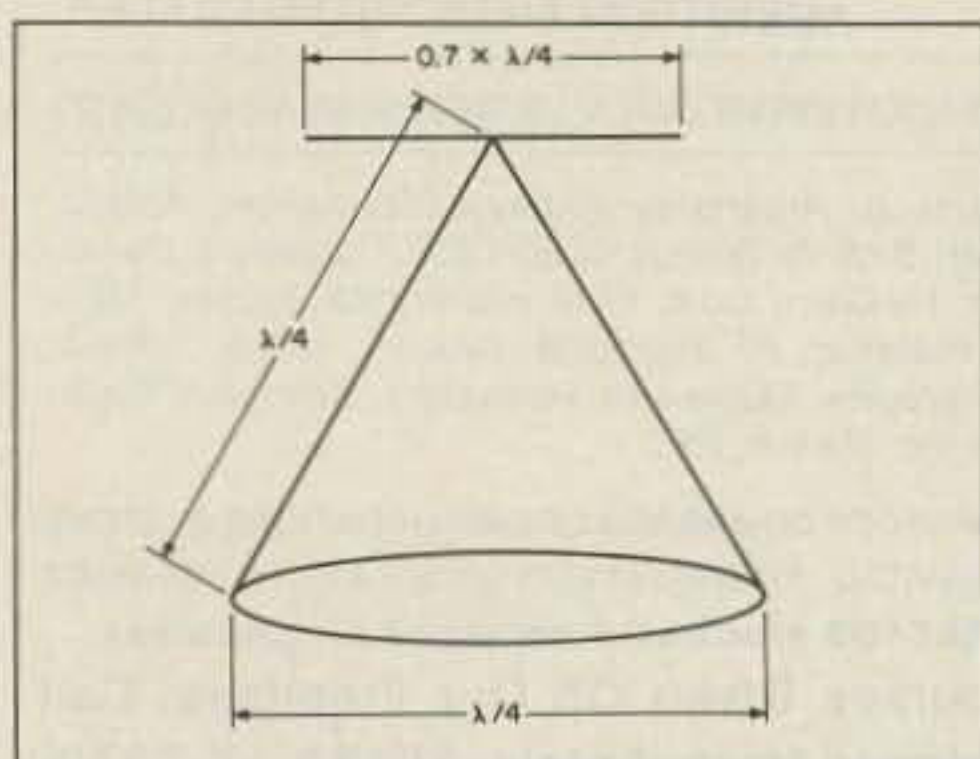


Figure 1. Design for the discone antenna.

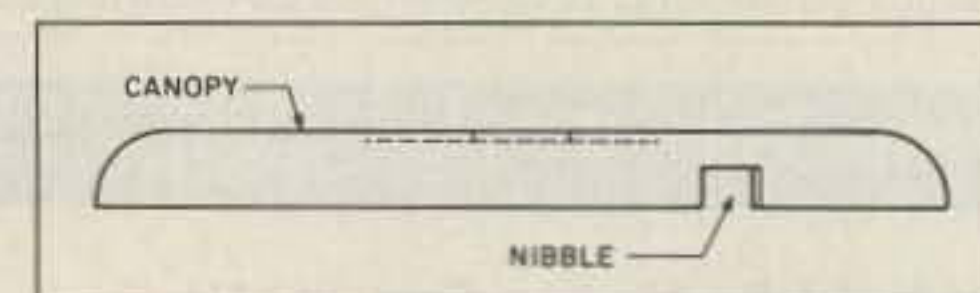


Figure 4. Modifying the light fixture canopy.

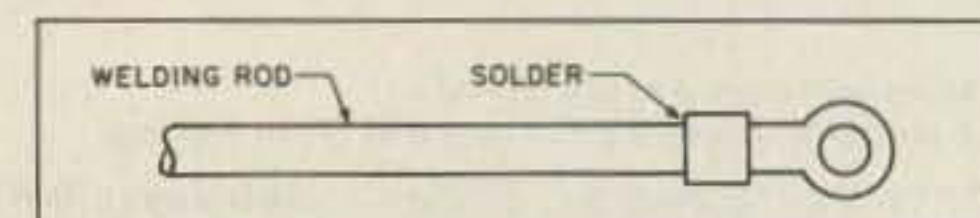


Figure 5. Element preparation.

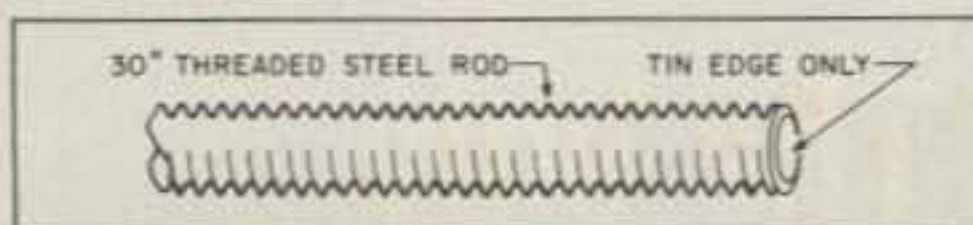


Figure 6. Tinning the pipe.

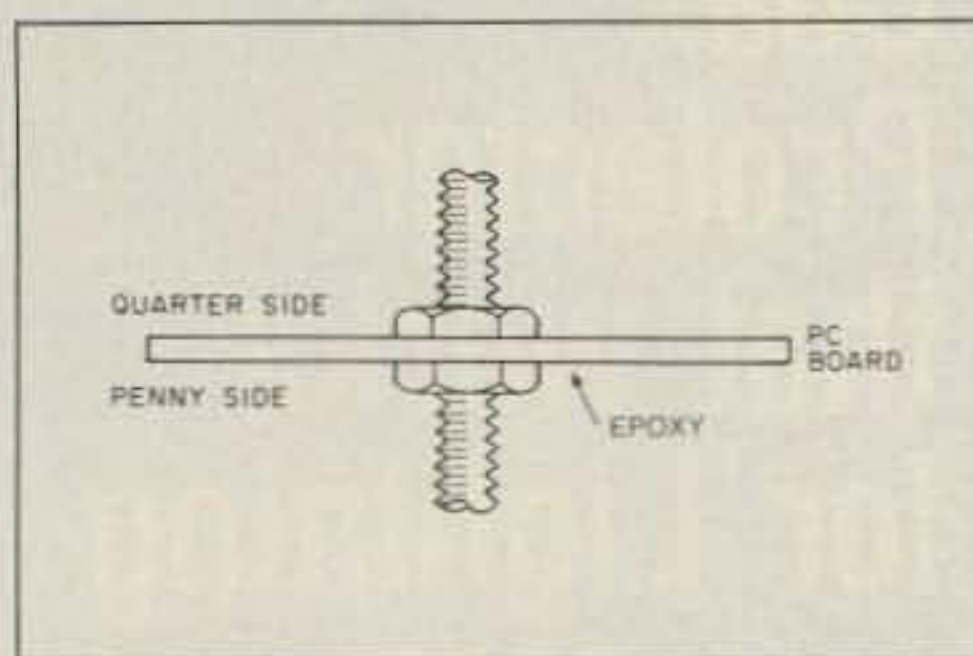


Figure 7. Disk support assembly.

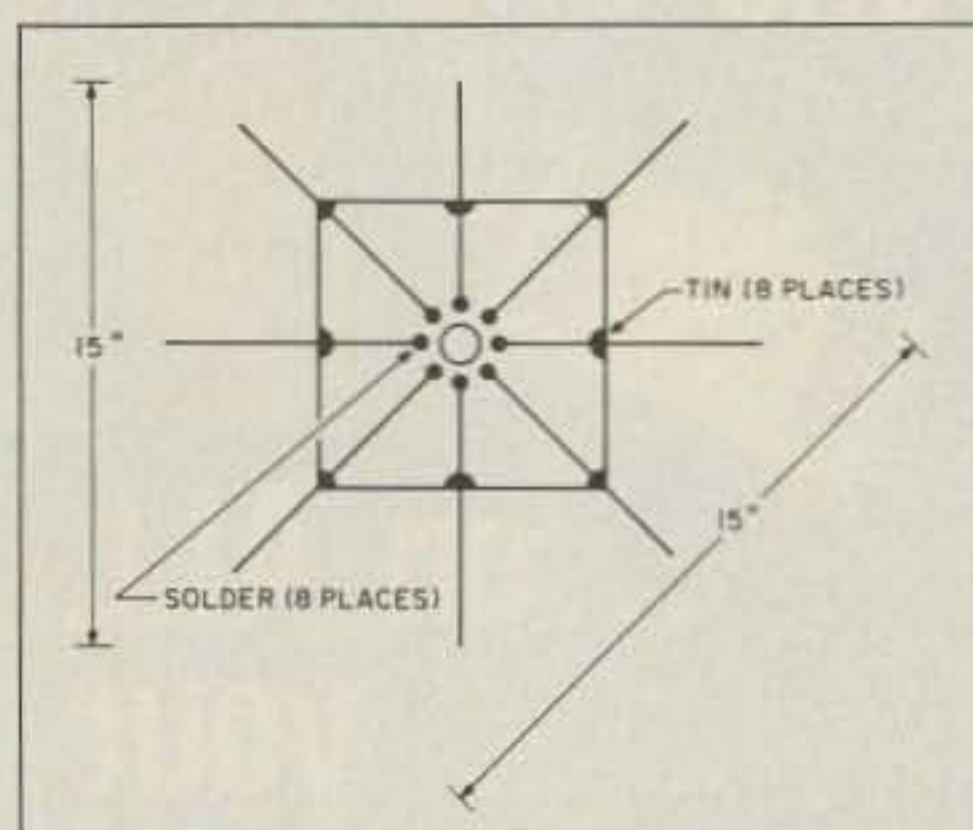


Figure 8. Tinning and soldering the top of the PC board.

not difficult to tin since it is made of steel, which doesn't conduct heat away as fast as copper or brass does. Cut 1" of the outer insulation off the RG-8M coaxial cable, separate the braid, and then fold it back over the cable insulation. Insert this end of the RG-8M cable into the non-tinned end of the 30" lamp pipe and push the cable through until the braid is flush with the tinned end of the pipe. Solder the braid to the pipe at this point.

Next, prepare the disk support printed circuit board. Insert a short length of steel lamp pipe (provided with the canopy kit) through the center hole in the printed circuit board and fasten it securely in place with two brass nuts. See Figure 7. Epoxy the brass nut to the PC board opposite the foil side. Be careful not to get epoxy on the threads. Now, remove the nut from the side of the board not epoxied, and unscrew the steel pipe from the nut still attached to the PC board. The side of the PC board with the nut will now be referred to as the bottom of the disk support PC board.

On the top of the PC board, tin each corner and tin the midpoint of each side. See Figure 8. Now solder down the 7 1/4" welding rods to the PC board, making sure that the total length from outer point to outer point is 15". You are creating a disk 15" in diameter out of the eight welding rods. Now go back and solder the inside edge of the welding rods to the PC board. Finally, place the 1" diameter brass washer over the ends of the welding rods centered over the hole in the PC board and solder the washer to the rods. See Figure 9.

Now it's time to start assembling the antenna. First, screw the end of the 30" pipe with the RG-8M center conductor sticking out into the nut on the bottom of the PC board. Screw it in just far enough so the end of the pipe is flush with the printed circuit side of the soldered down nut. The center conductor of the RG-8M will pass through the center of the brass washer on the top of the PC board.

Next, place the solder lugs of the eight long steel welding rods over the 30" steel pipe and hold them in place with a 1/8IP brass nut. Put this nut on finger-tight and then arrange each long rod so that it is exactly under each short rod on the top of the PC board. Carefully tighten the brass nut. Thread another brass nut on the steel pipe and position it about 3" below the nut holding the long rods in place. Hold the pipe upright with the PC board at the upper end, then bend all

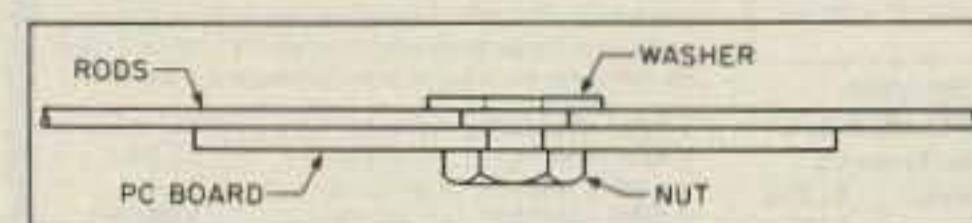


Figure 9. Finishing the PC board.

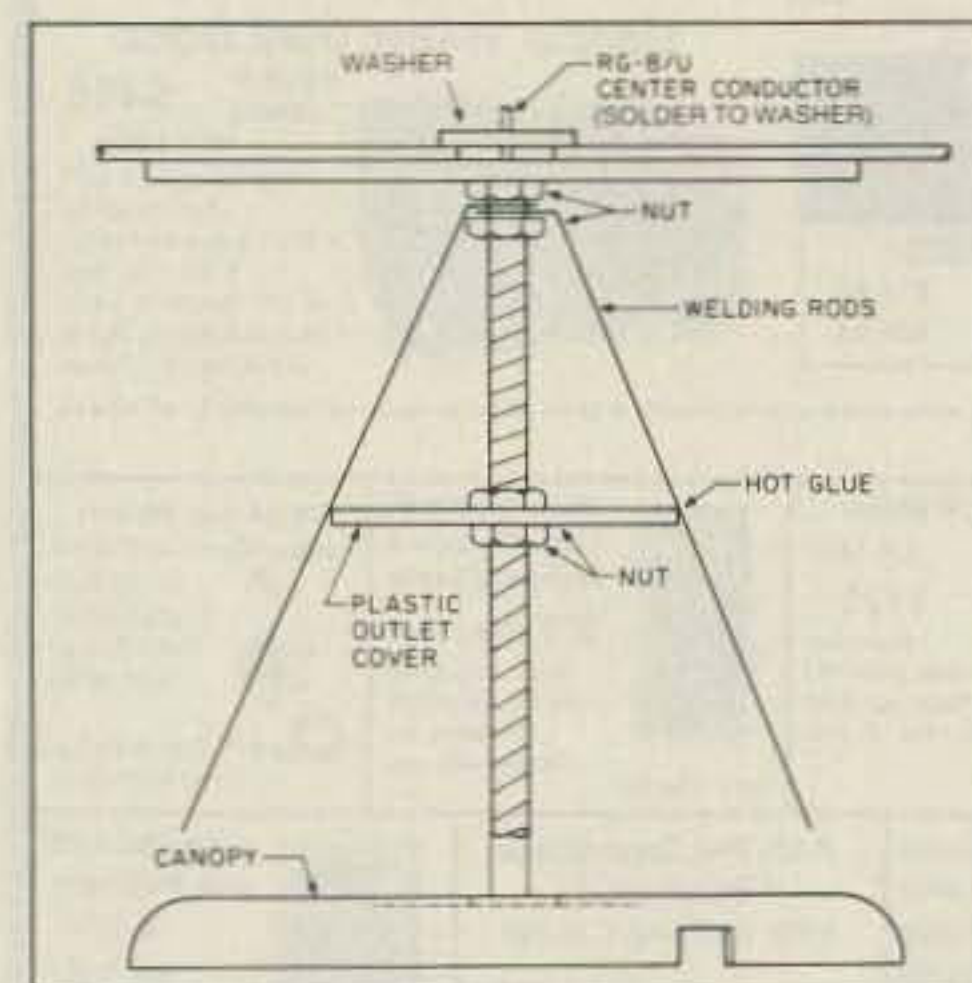


Figure 10. Assembling the discone.

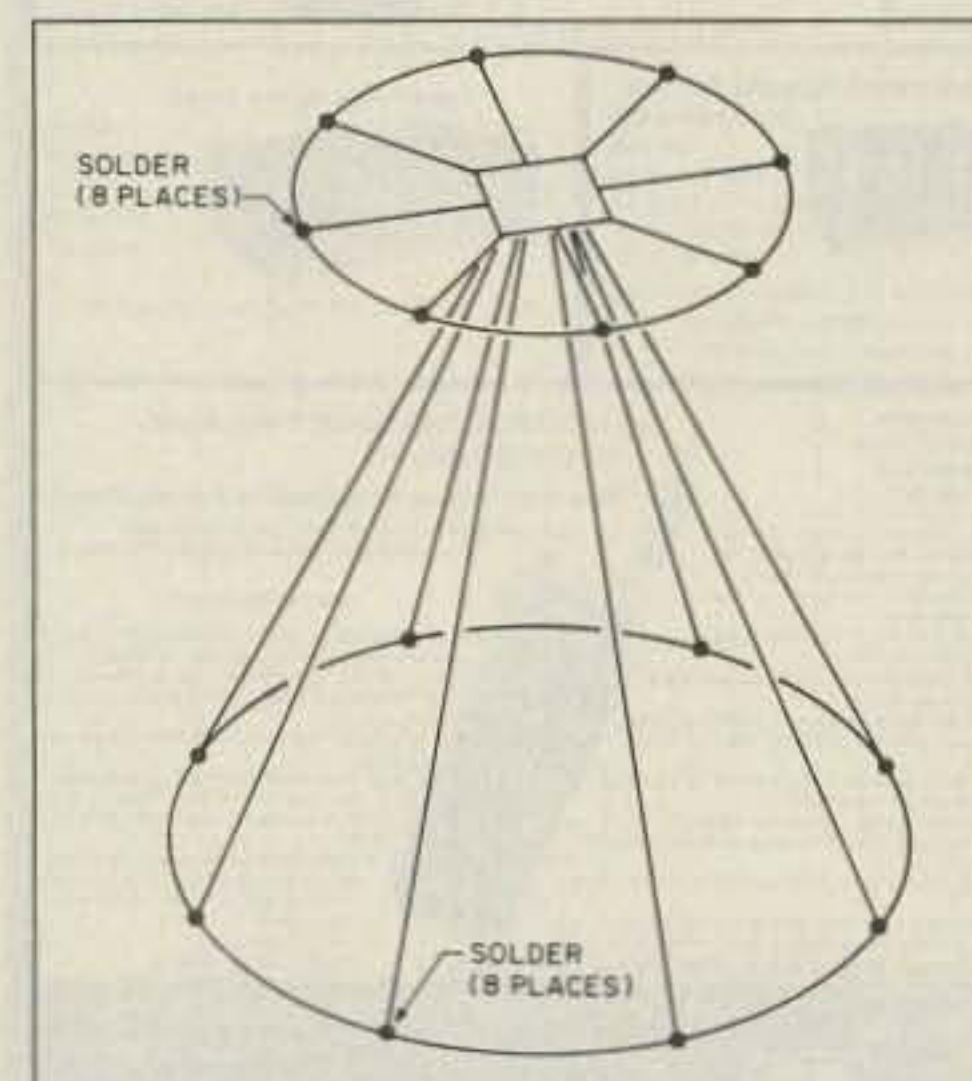


Figure 11. Wire placement.

Description	Parts List	Approximate Cost
1" diameter brass washer		\$.10
30" 1/8IP all-thread steel lamp pipe		\$ 3.17
1 light fixture canopy kit		\$ 2.45
6 brass 1/8IP nuts (pkg. of 6)		\$.99
1 plastic 4" round electrical box cover		\$.17
10 feet #12 copper wire (\$.07/ft.)		\$.70
8 copper plated steel welding rods (\$.20 ea.)		\$ 1.60
12" x 24" x 1" piece of wood		\$ 1.00
4 1/2" x 4 1/2" single-sided PC board		\$ 3.99
6 3/8" solder lugs (RS 64-3040 x 3)		\$ 3.87
5 feet RG-8M (RS 278-1328 0.27 x 5)		\$ 1.35
Total		\$19.39

the long rods down along the steel pipe. Place the plastic electrical outlet cover over the steel pipe and thread on another brass nut. Push the electrical outlet cover up the pipe and spread the long welding rods until the bottom ends of the rods are 21.5" apart from their opposite rod. Adjust the nut positions as necessary and tighten the nuts to hold the electrical outlet cover in place. See Figure 10. I used a hot glue gun to attach the long welding rods to the plastic electrical outlet cover to help with the antenna rigidity, but this is not really necessary.

Strip the insulation off the RG-8M center conductor as it passes through the brass washer on the top of the printed circuit board. Solder the center conductor to the brass washer. Now, mount the antenna to the canopy by threading another brass nut over the end of the steel pipe, passing the cable and pipe through the hole in the canopy, and threading another nut over the pipe and tightening it. You can now attach the canopy to a piece of wood (I used a 1' x 1' x 1" board), thus allowing the antenna to stand freely.

The last thing to do is to solder a piece of #12 copper wire around the circumference of the disk and cone. Cut a 50" piece of wire for the disk and a 70" piece of wire for the base of the cone. Tin the ends of each of the welding rods and solder the copper wire to them. See Figure 11. Though it is not really necessary to tie all the welding rod ends together, this and the hot glue mentioned earlier make the antenna very rigid.

Finally, attach your connector of choice to the end of the RG-8M coming from the discone. RG-8M has the same dimensions as RG-59. A PL-259 UHF connector with a RG-59 reducer or a BNC connector for RG-59 cable work well.

Operation

How does it work? I measured an SWR of less than 1.5 to 1 on all ham bands between 144 and 1296 MHz. I placed the antenna on its wood base in my attic and it provides excellent general coverage reception, as well as transmission in the covered ham bands. Not bad for about an hour's worth of work and less than \$20 worth of parts! **73**

Contact Phil Salas AD5X at 1517 Creekside Drive, Richardson TX 75081.

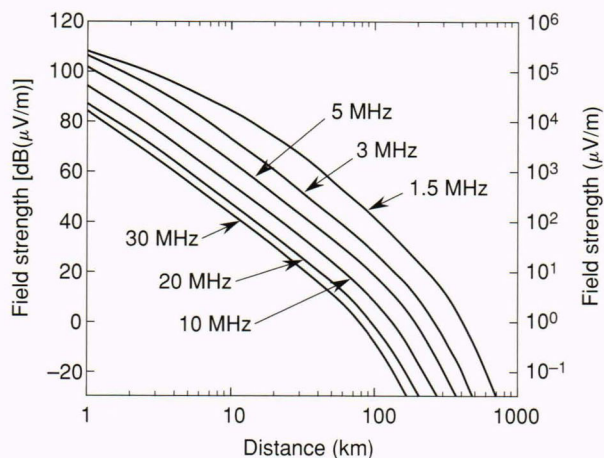


Figure 2. Ground wave propagation curves for wet ground (conductivity = 10^{-2} s/m, dielectric constant = 30). Provided by the International Radio Consultative Committee.

conductivity and dielectric constant representative of wet ground. The radiating element is assumed to be a short vertical monopole at ground level radiating 1 kW. The receiving antenna is also at ground level at various distances across a smooth, homogeneous, spherical Earth. The data, provided by the International Radio Consultative Committee,² show that the lower the frequency, the greater the ground wave range, all other things being equal. In addition, theory shows that ground wave propagates over wet ground better than dry ground.

Often, the highest-priority design goal of the communicator is to achieve the maximum range possible. Consequently, one usually associates ground wave communication with frequencies in the lower part of the HF band and below. Lower frequencies, however, require large, stationary antennas for efficient radiation. In the effort described in this article, a particular, relatively short (about 40 km) range was desired. Equally important as achieving the desired range were the requirements for reliability in a nuclear environment, non-line-of-sight connectivity in mountainous terrain, and a portable, unobtrusive antenna.

SELECTION OF THE BAND

To achieve the maximum range with the lowest power, the use of a resonant antenna was desirable for both transmission and reception. Conversely, optimum portability was sought. With these constraints in mind, 20 MHz was chosen as the lower limit of the frequency band to be tested. A resonant antenna could then be constructed with a height of less than 4 m. The upper frequency was taken to be 30 MHz because this is the upper limit of the HF band and the cutoff point of most military HF transceivers. The 20- to 30-MHz band offers additional advantages. As we will show, ranges of interest are achievable in mountainous terrain with reasonable transmission power levels. Beyond the ground wave range, however, a skip zone exists that extends for hundreds of miles, wherein no ground wave or sky wave is present (Fig. 1). Accordingly, for signals transmitted in the 20- to 30-MHz

band, there is a large region surrounding the area of communication coverage from which it is unlikely that one could intercept or determine the location of the radiating antenna. Beginning at about 800 km, interception of a skipped signal occurs a few percent of the time. Although the skip probability increases beyond this point, the error associated with locating a transmitting source also increases.

A further advantage of the chosen band is the relatively low noise level, particularly in rural areas, where HFGW might be used. In urban environments, wideband noise signals from electrical equipment can be a source of annoyance; however, these are extremely limited in range. The few other users of this band are likely to be transmitting from a nonresonant antenna or one that is horizontally polarized, and thus the resulting ground wave is weak. Consequently, competing noise sources within ground wave range are few and weak in rural areas. In and around cities, one might find competing signals in certain frequency ranges or at certain locations, particularly during the day; however, if one scans the spectrum from 20 to 30 MHz, one finds the overall noise background to be significantly lower than that in the lower portions of the HF band.

Interfering distant stations are limited by the skip characteristics discussed earlier. At night this band is particularly quiet as local noise sources are extinguished, and the probability of distant signals skipping decreases, particularly after midnight. This contrasts with the environment found in the lower part of the HF band, where short-range communication suffers at night since it is more difficult for the ionosphere to support high angle skips, and the fading of the absorbing part of the ionosphere (D layer) allows distant stations to interfere. A study by Laycock et al.³ of percent congestion values versus frequency range documents this phenomenon for the environment of western Europe. Data taken at a rural site in central England show no congestion for most frequency intervals in the 20- to 30-MHz band. By contrast, the lower region of the HF band was almost 100% occupied, particularly at night.

PROPERTIES OF THE DISCONE ANTENNA

Military users need HFGW signals that can change frequencies quickly to avoid jamming and reduce the probability of interception. Furthermore, portability and speed of erection and disassembly are important. The disccone antenna was found to have the desired characteristics. This antenna, comprising a disc and a cone, is omnidirectional and wideband, with a nominal $50\text{-}\Omega$ impedance that produces vertically polarized radiation.^{4,5} For HF and very-high-frequency (VHF) applications, the disc and cone are usually not solid, but are made up of spokes. The height of the antenna is set by the length of the cone spokes, which are chosen to be equal to one-quarter the wavelength of the lowest desired frequency (cutoff frequency) and the cone angle, which is typically 30° . (For optimum performance, the cone spokes are chosen so that the cutoff frequency is taken to be about 1 MHz lower than the lowest frequency to be used.) Figure 3 shows the

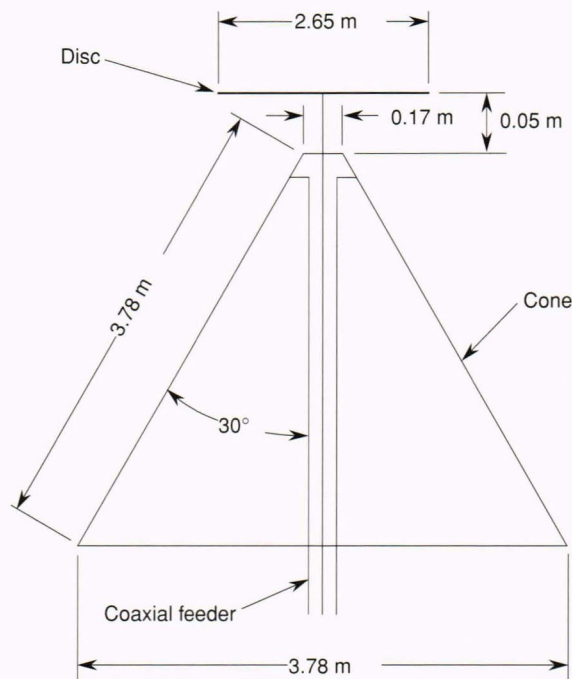


Figure 3. Dimensions for a discone antenna with a cutoff frequency of 19 MHz.

dimensions of the discone antenna used in the work described in this article. Eight spokes were used on the disc and cone for the first discone built at APL. Subsequently, a discone was tested that used only six spokes on the disc and six for the cone. No difference in performance was measured between the two configurations.

Beginning just above the cutoff frequency, the discone antenna has had a good voltage standing wave ratio (VSWR) for many decades. Figure 4 shows the VSWR versus frequency measured for a discone antenna having a cutoff frequency of 19 MHz. A 50- Ω HF transceiver will transmit and receive efficiently on this antenna throughout the 20- to 30-MHz band without the need for an antenna matching unit. Also, the discone lends itself to using spread spectrum or frequency hopping techniques throughout this 10-MHz band.

The discone antenna can be made portable. Erected, it stands about 4 m high. Experience has shown that this size is reasonable for use in wooded, tactical positions. A discone antenna has been fabricated at APL that weighs less than 3 kg and can be carried by backpack when disassembled. Assembly and disassembly each take about ten minutes.

MEASUREMENTS OF HFGW PROPAGATION OVER DIFFICULT TERRAIN

Using discone antennas and frequencies in the 20- to 30-MHz band, HFGW ranges have been measured in several environments. Initially, measurements were made in the mountains of western Germany, in a region representative of the Pershing operational environment.⁶ Later in the program, range measurements were performed elsewhere to demonstrate the applicability of the technique to other systems.⁷

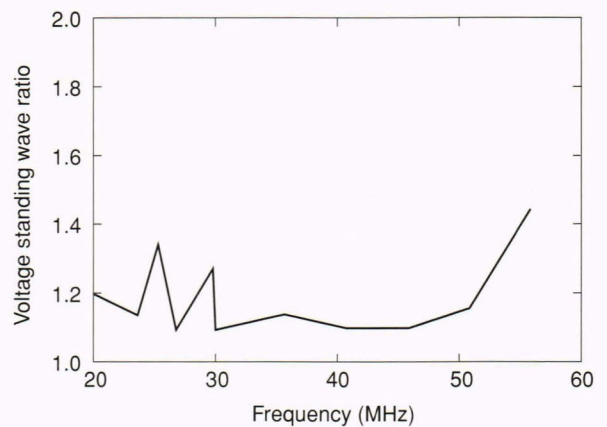


Figure 4. Voltage standing wave ratio versus frequency for a discone antenna with a cutoff frequency of 19 MHz.

Propagation in the Mountains of Western Germany

Using a discone as the base station antenna, single-sideband (SSB) voice and continuous wave (CW) test signals were transmitted at 26.725 MHz. The output power was 100 W. Identical results were obtained using both military (AN/GRC-193A transmitter) and civilian (Yaesu model 757GX transceiver) radio equipment. A second discone antenna was moved to positions increasingly distant from the base station. At each test site, voice contact was established and a CW signal was transmitted. At the receiving location, measurements were made of the CW signal-plus-noise level and noise background using another Yaesu transceiver that had been calibrated by injecting known CW power levels and measuring the audio power out. Using this method, suggested and implemented by J. D. Colson of the Space Department, a calibration curve was constructed that one could use to relate the measured audio signal to the CW signal being received.

Figure 5 shows the region in which four of the paths were surveyed. The signal-plus-noise to noise ratios (S/N_s) and the received power levels measured over the four paths are given in Table 1. Only path 1 into the Schwäbian Alps represents a maximum range. (Maximum range was defined as the greatest distance at which an intelligible voice signal could be received. Quantitatively, this was taken to be the point where the CW was about 10 dB. Although the S/N was less than 10 dB over path 1, the voice signal was intelligible. Furthermore, the test team did not have total flexibility in selecting sites because of administrative constraints.)

Even though signal levels indicated that greater range was possible along the other paths, the test team could not proceed further because permission had not been received from the host government.

All paths listed in Table 1 were mountainous and were not line-of-sight. To illustrate, Figures 6 and 7 show paths 1 and 4, respectively. Elevation in meters is plotted against distance in kilometers. The transmitter was located at the 0-km point, and signal measurements were made along the path. An attempt was made to find points in the valleys along the path where dropouts would occur; none were found, however.

A Discone Antenna for 10 Meters

It looks like a bird cage, but works like a yagi.

by O.B. Boddie W1ZB/6

A truncated cone antenna is a superior radiator, equaled by none. The cone antenna is used extensively on VHF and UHF, and the Skelton cone is a version of it for HF.

The discone antenna described in this article resembles the old cage antenna of the spark days. My XYL says it looks like a bird cage. But, looks can be deceiving. This small antenna was tested extensively, with a

6-dB gain three-element yagi as a standard. It proved equal to the yagi in every way.

This discone antenna has a gain of 6 dB across the entire 10 meter band. How does it do this? It has an infinite number of half waves in parallel for a radiation pattern. It always has the right angle of radiation because of the rotating field pattern.

You can build it as a single cone 5 feet high to sit on the roof, giving you a 3-dB gain in all directions at a low angle. This is fine for apartment dwellers and works well from the inside of the apartment because of the multi-angle radiation pattern. It is easy to construct and the cost is so low that anyone can afford to build it. Or, you can construct two cones separately and hang them both from

the ceiling or under the eaves on a house or garage. Mine are hung in the shape of an inverted "V" and favor signals broadside. Mounted vertically, it radiates in all directions with a 3-dB gain when using only a 5-foot antenna.

The low angle of radiation makes this cone an excellent DX antenna. It even picked up a few new countries I could not raise on the yagi! For 20 me-

ters, double all measurements and you can have a 6-dB gain antenna on 14 MHz.

If you are using a single cone antenna, no tuner is necessary. On the discone antenna, however, an antenna tuner may be necessary for a perfect match.

Construction Details

These details are for a single cone. Make two of them for a discone.

"This is fine for apartment dwellers and works well from the inside of the apartment because of the multi-angle radiation pattern."

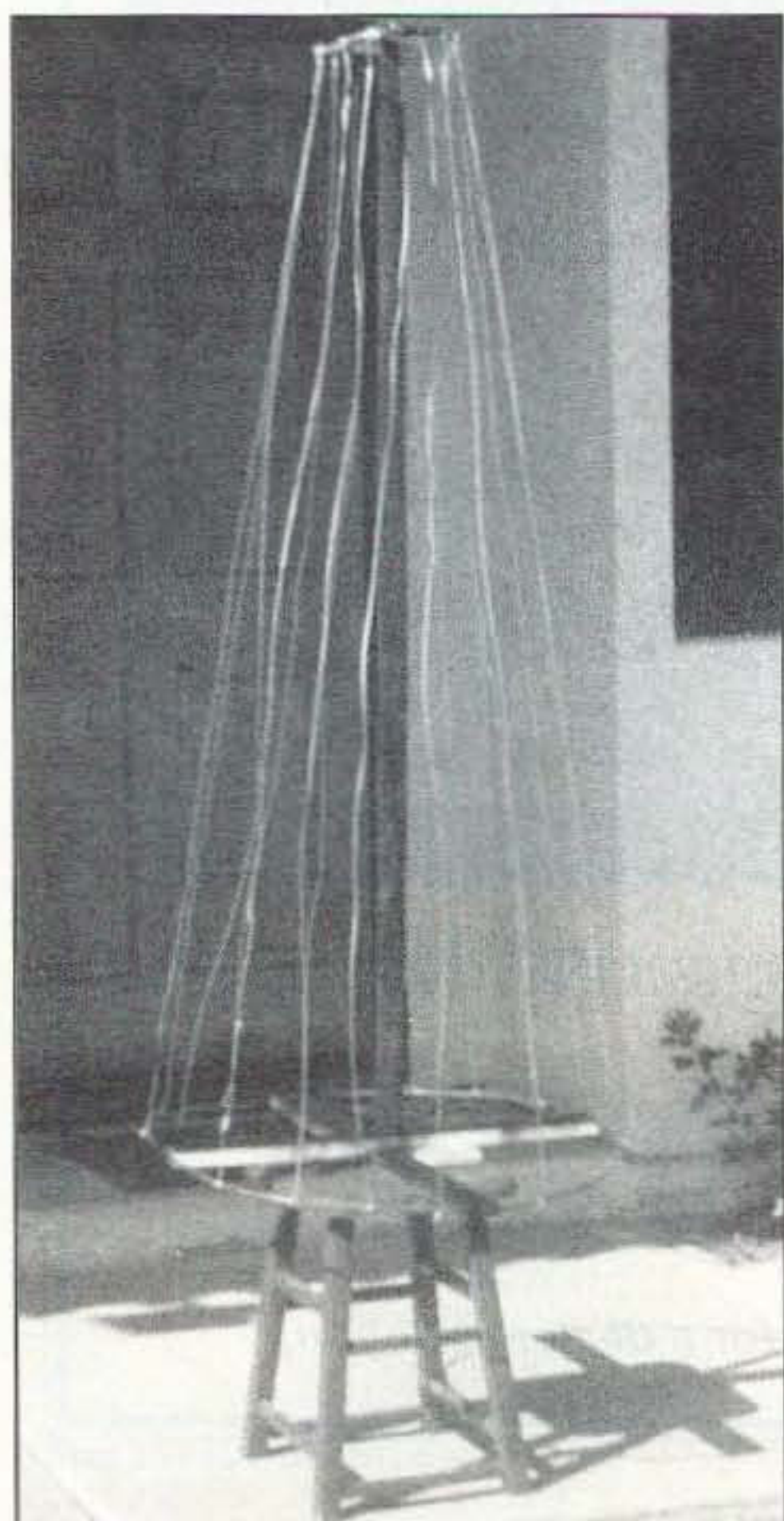


Photo A. Finished discone antenna.

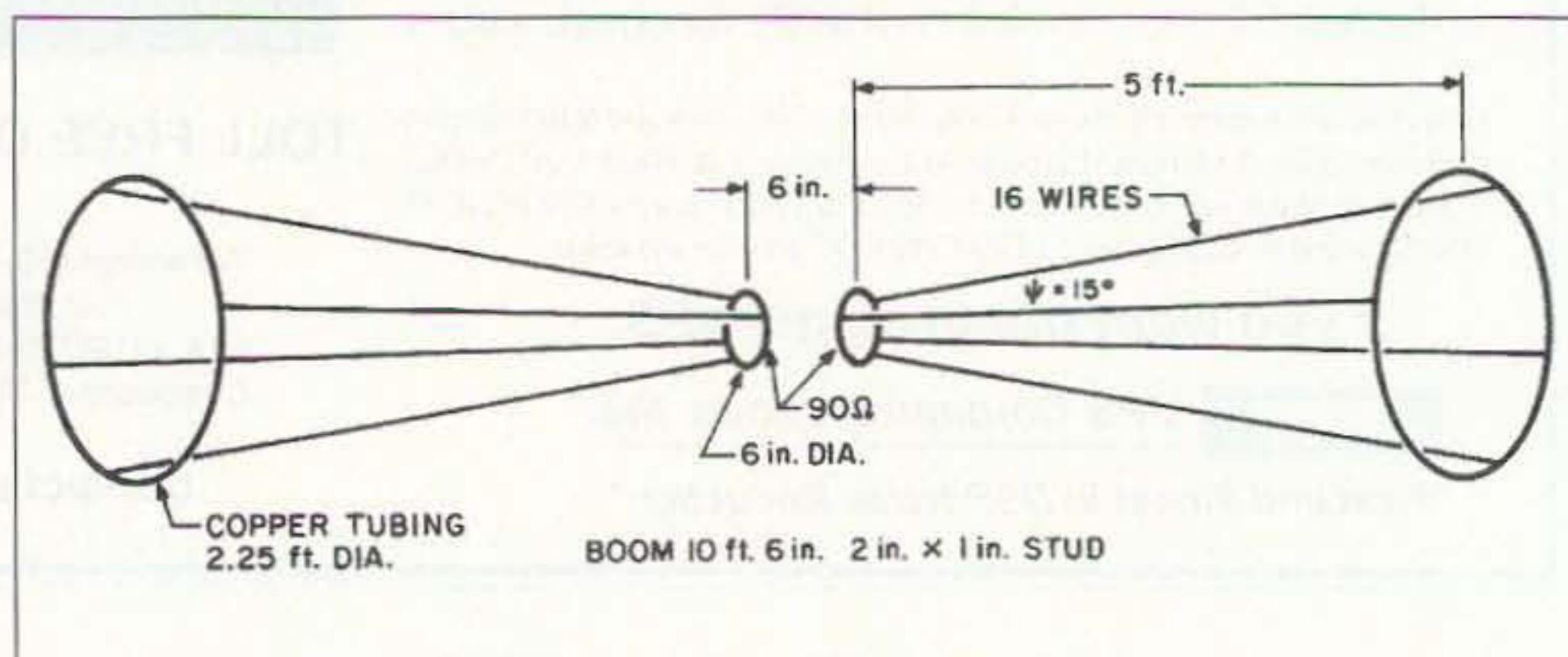


Figure 1. Discone for 10 meters.

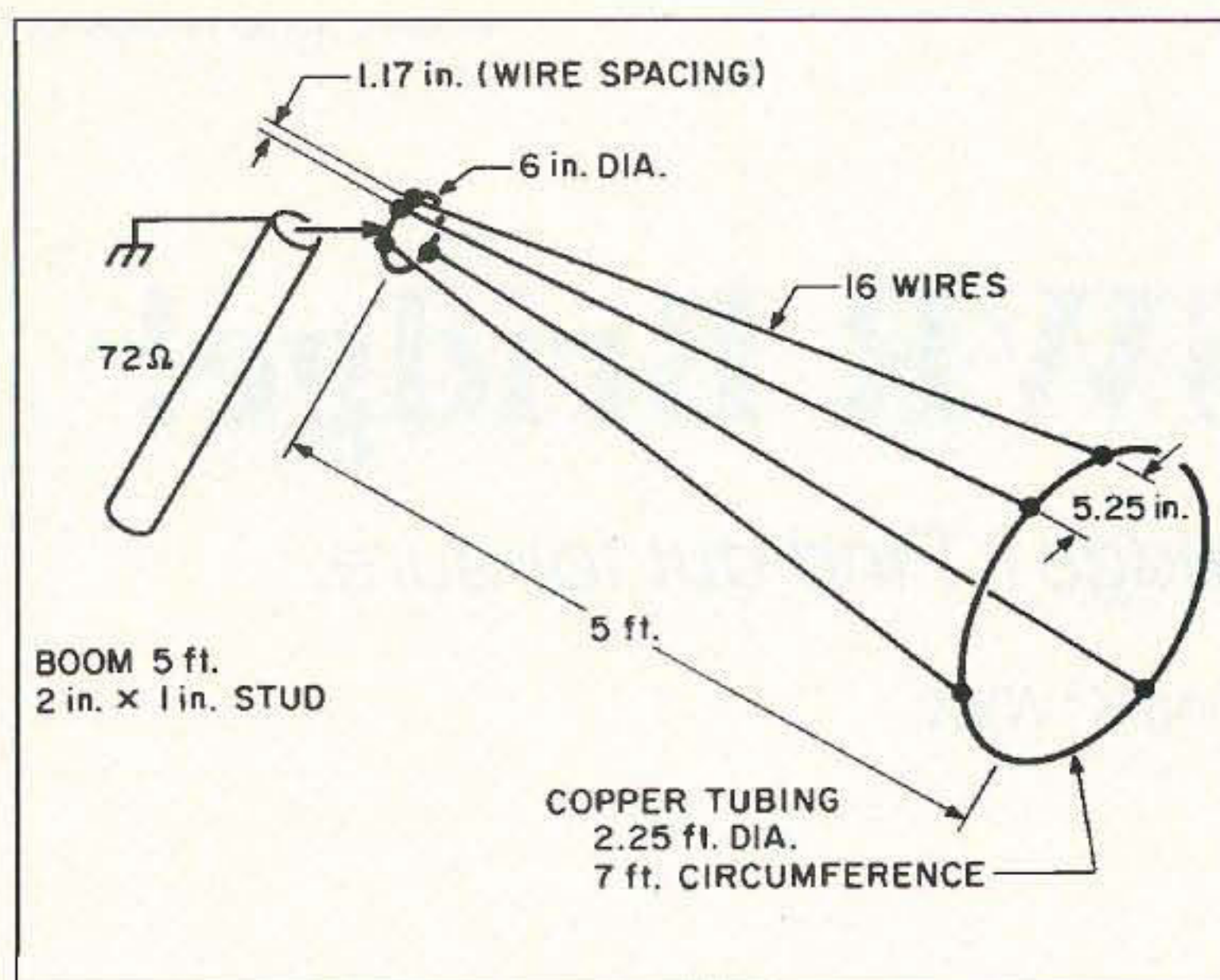


Figure 2. A 10 meter conical.

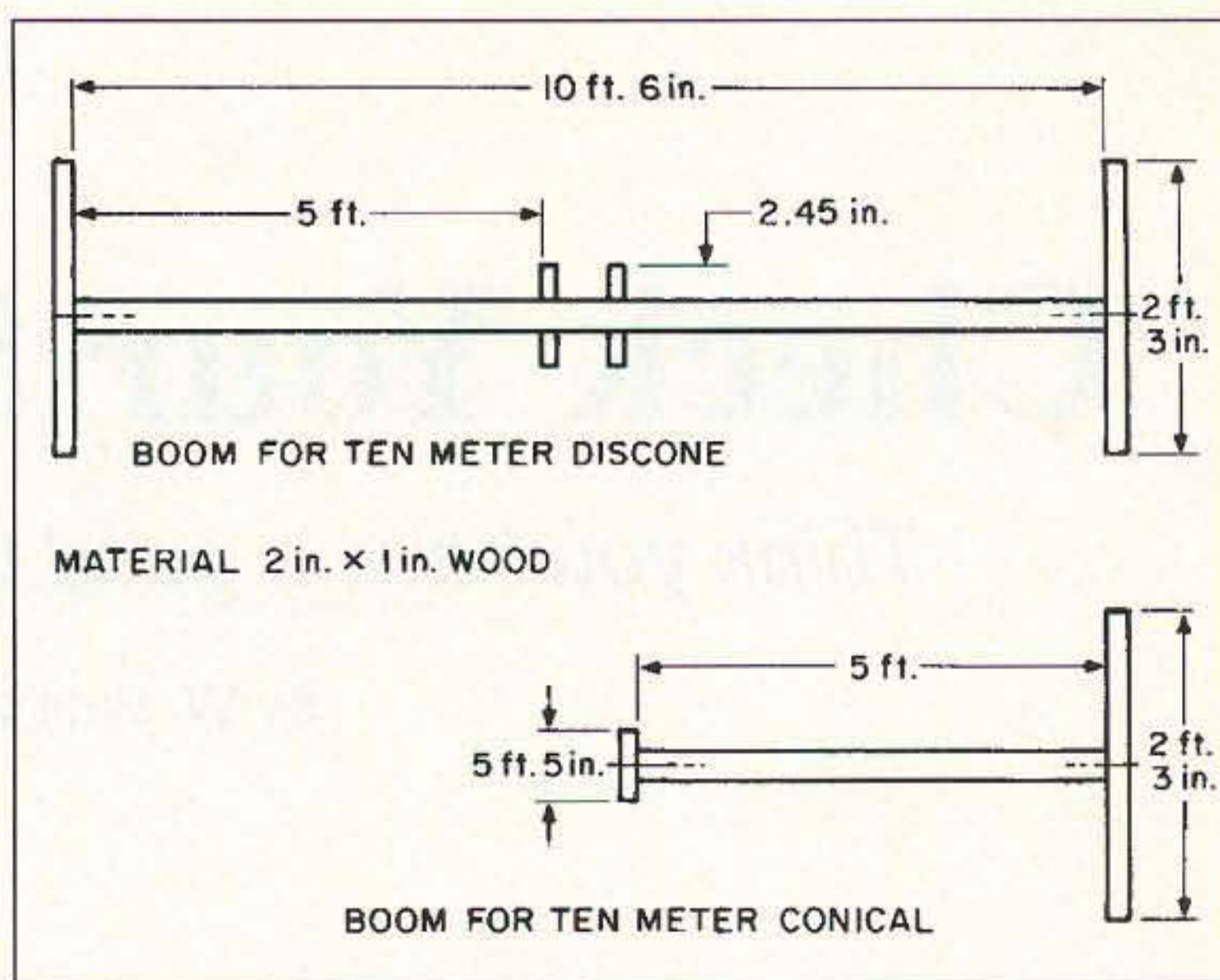


Figure 3. Boom for conicals.

First, make the booms, following the details in Figure 1. Next, cut a 7.20-foot piece of copper tubing. Flatten one inch on the ends with a hammer. Bend it in a circle. Drill through the flattened ends with a #18 drill clearance for an 8-32 machine screw.

Cut off a 20-inch piece of copper tubing. Flatten 1 inch on the ends with a hammer. Bend this piece of tubing in a 6-inch circle. Drill through the flattened ends with a #18 drill clearance for an 8-32 machine screw.

Bolt together the two copper tubing circles with 8-32 machine screws.

It is easy to construct and the cost is so low that anyone can afford to build it.

Insert the tubing circles onto the boom for fit. Shave down the wood for fit. Flatten the copper tubing where it goes over the 2-inch by 1-inch ends of wood.

On both the large and small loops, drill two holes through the copper at the flat

portion to clear 5/8-inch by 8-inch wood screws. Remove the copper tubing loops and drill 1/16-inch holes, evenly spaced, in 16 places on each copper tubing loop.

Assemble boom and copper tubing loops together. Tighten the wood screws to hold the assembly together. String 16 wires as per Figure 4 after scraping enamel off the ends of wire for good contact.

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Parts List (for one cone; double for discone)

- 10 feet of 1/4 inch copper tubing
- 100 feet of #18 copper wire enamel covered
- 32 each 3/8 inch #6 pan head sheet metal screws
- 2 each 1 1/2 inch #8 flat head Phillips brass wood screws
- 2 each 8-32 1/4 inch-long machine screws and nuts
- 1 five-foot 2 inch x 1 inch wood stud for boom
- 1 two-foot-3-inch 2 inch x 1 inch wood for end piece
- 1 six-inch 2 inch x 1 inch wood for end piece
- Note. For the discone, two cones make the boom 10 ft. 6 inches long.

Construction

1. Make booms as per drawing.
2. Cut off a 7-foot 3-inch piece of copper tubing. Flatten 1 inch on ends with hammer. Bend it in a circle.
3. Drill through flattened ends with a #18 drill clearance for an 8-32 machine screw.
4. Cut off a 20-inch piece of copper tubing. Flatten 1 inch on ends with hammer. Bend it in a 6-inch circle.
5. Drill through flattened ends with a #18 drill clearance for an 8-32 machine screw.
6. Bolt together copper tubing circles with 8-32 machine screws.
7. Insert copper tubing circles on to the boom for fit. Shave down wood for fit. flatten copper tubing where it goes over 2 inch x 1 inch ends of wood.
8. Drill two holes through copper at flat portion to clear 1 1/2 inch x 8 wood screws.
9. Do this for large and small loops of copper tubing.
10. Remove copper tubing loops and drill 1/16 inch holes in 16 places on each copper tubing boom evenly spaced.
11. Assemble boom and copper tubing loops together. Screw down wood screws to hold assembly together.
12. String 16 wires as per drawing after scraping enamel off the ends of wires for good contact.

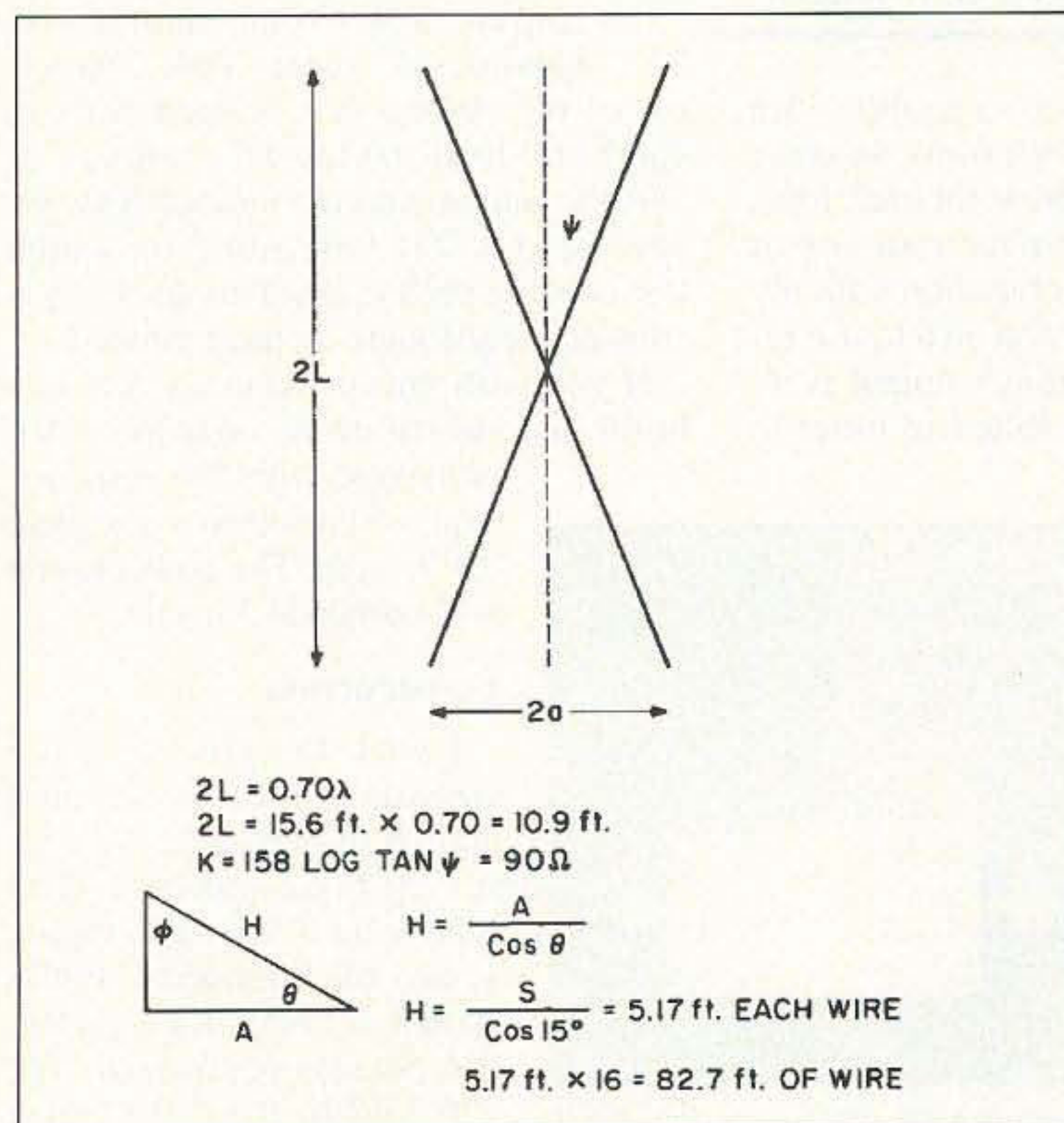


Figure 4. Conical math.



US005608416A

United States Patent [19]
Champion et al.

[11] **Patent Number:** **5,608,416**
[45] **Date of Patent:** **Mar. 4, 1997**

[54] **PORTABLE RAPIDLY ERECTABLE
DISCONE ANTENNA**

0031203 2/1982 Japan 343/896
1502100 5/1975 United Kingdom 343/773
1508784 4/1978 United Kingdom 343/846

[75] Inventors: **James R. Champion**, Ellicott City,
Md.; **Denver N. Tenney**, Vienna, Va.;
Laurence C. Simms, Baltimore, Md.

[73] Assignee: **The Johns Hopkins University**,
Baltimore, Md.

[21] Appl. No.: **557,871**

[22] Filed: **Nov. 14, 1995**

Related U.S. Application Data

[63] Continuation of Ser. No. 388,126, Feb. 13, 1995, abandoned,
which is a continuation of Ser. No. 49,334, Apr. 21, 1993,
abandoned.

[51] Int. Cl.⁶ **H01Q 13/00**

[52] U.S. Cl. **343/773; 343/846; 343/890;**
343/896

[58] **Field of Search** 343/846, 848,
343/773, 901, 847, 878, 888, 890, 891,
829, 896; H01Q 1/48, 13/00

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Primary Examiner—Donald T. Hajec

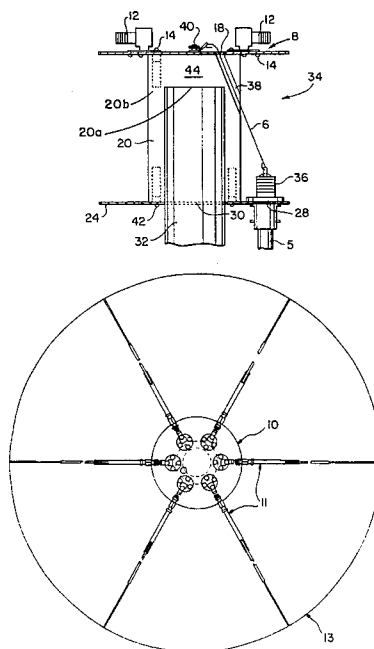
Assistant Examiner—Steven Wigmore

Attorney, Agent, or Firm—Mary Louise Beall; Eugene J.
Pawlikowski

[57] **ABSTRACT**

This invention is a lightweight, portable, quickly assembled,
wide band, discone antenna for high frequency ground wave
communication. The disk portion of the antenna is formed of
telescoping spokes and the cone portion is formed of sepa-
rate retractable wire elements. Disassembled, the antenna
can be carried in a backpack. It can be assembled in less than
ten minutes to achieve non-fading, non-line-of-sight com-
munication.

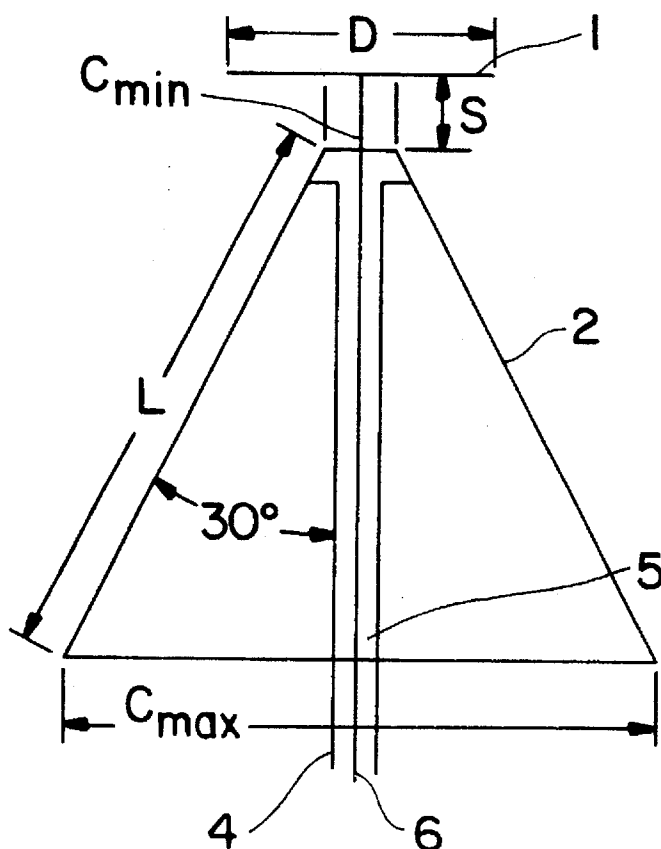
3 Claims, 7 Drawing Sheets



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FIG. 1



$$L = (\lambda/4) \times 0.96 = C_{\max}$$

$$D = 0.7 C_{\max}$$

$$C_{\min} \leq L/22$$

$$S = 0.3 C_{\min}$$

FIG. 2

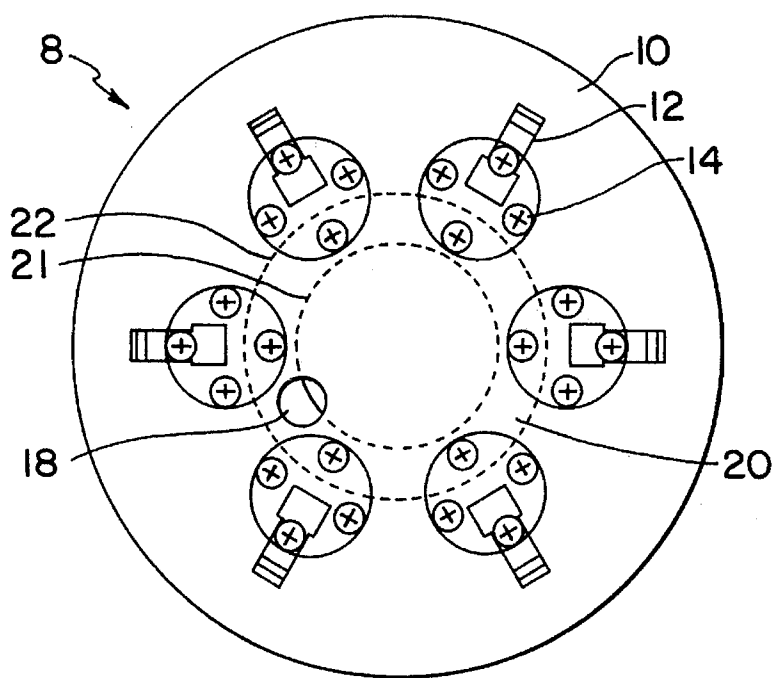


FIG. 3

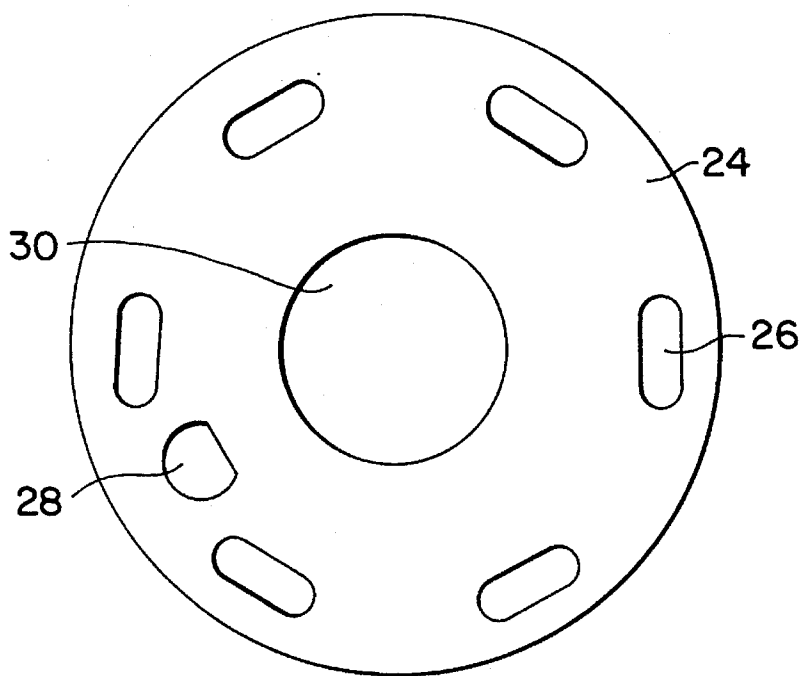


FIG. 4

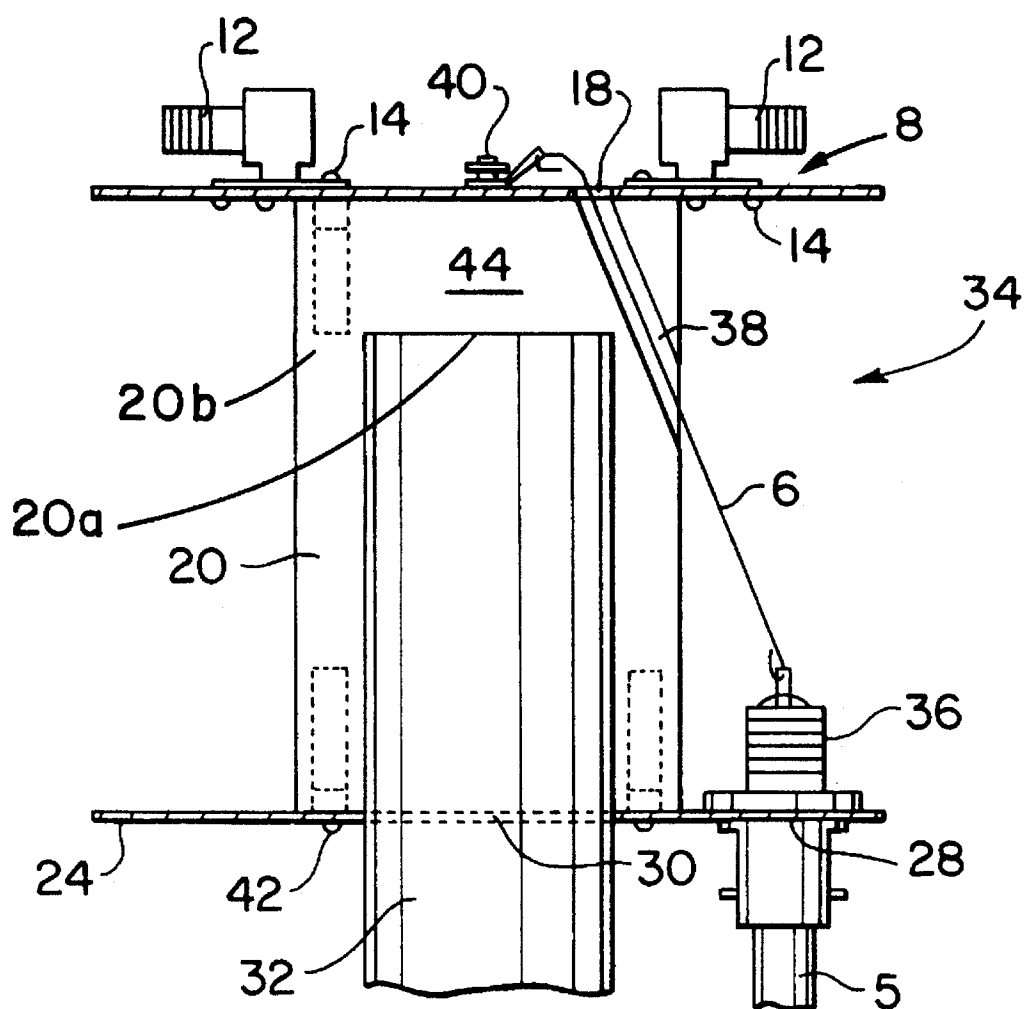


FIG. 5

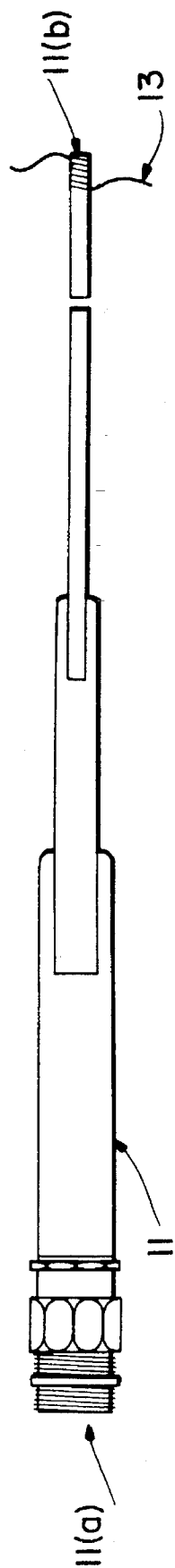


FIG. 6

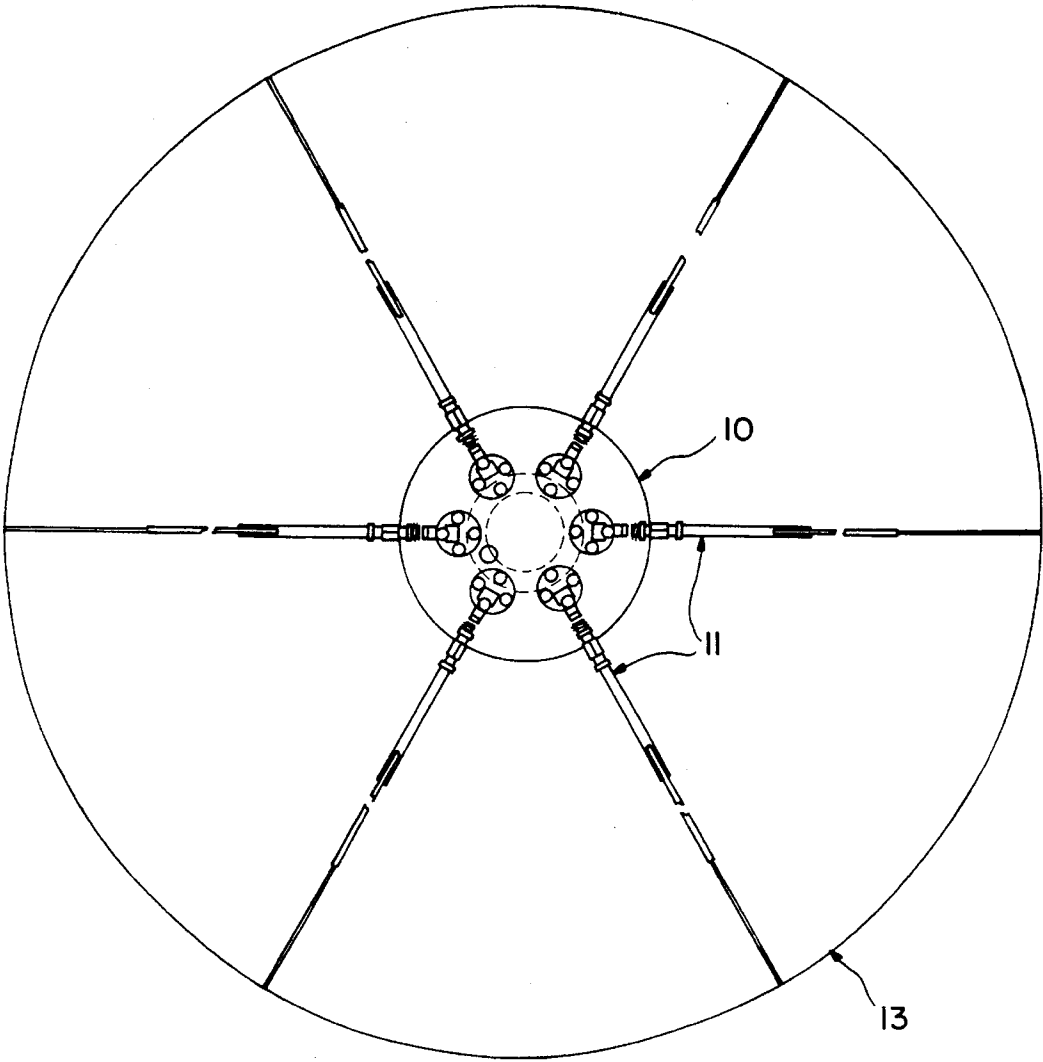


FIG. 7

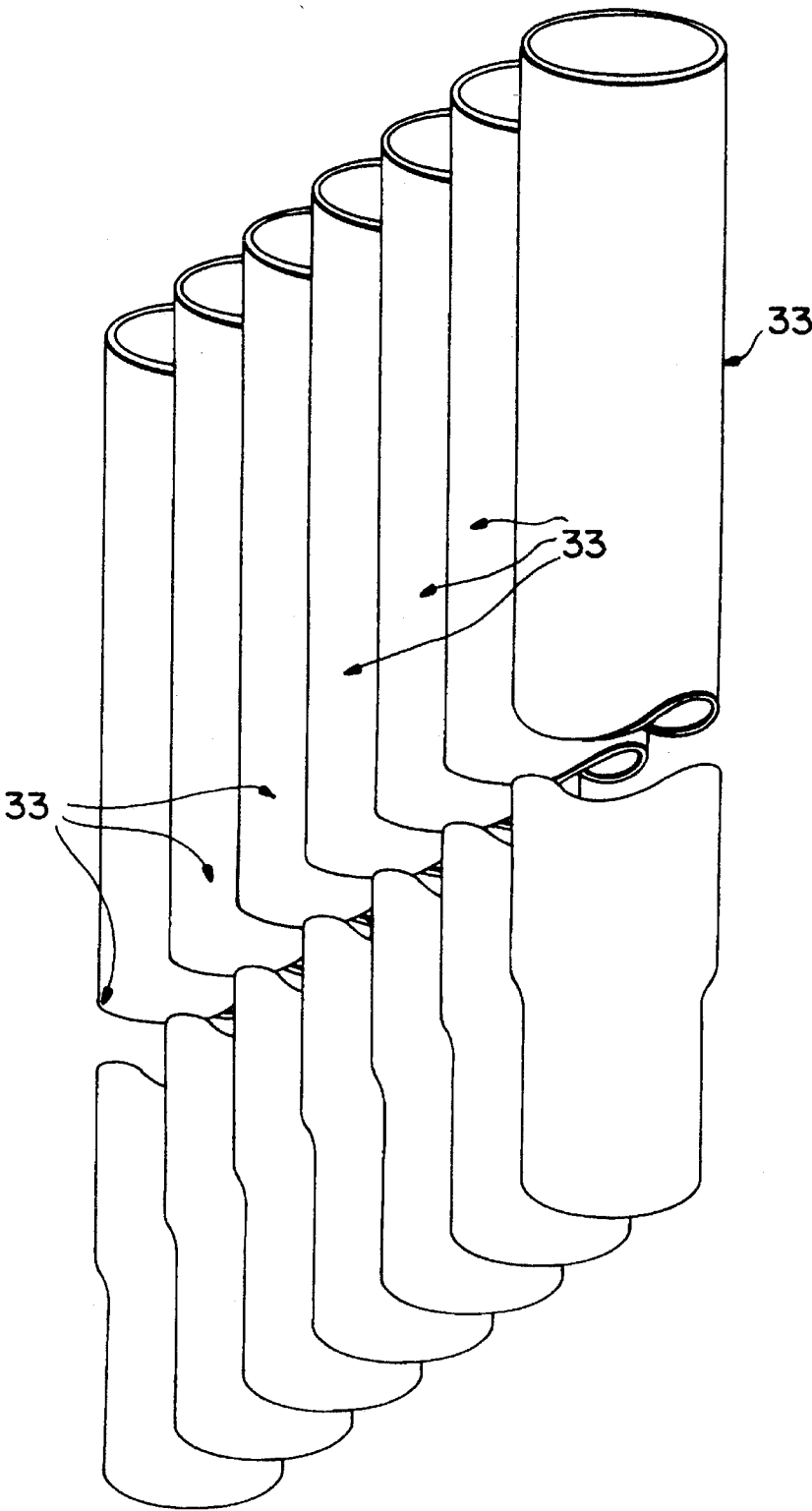


FIG. 8

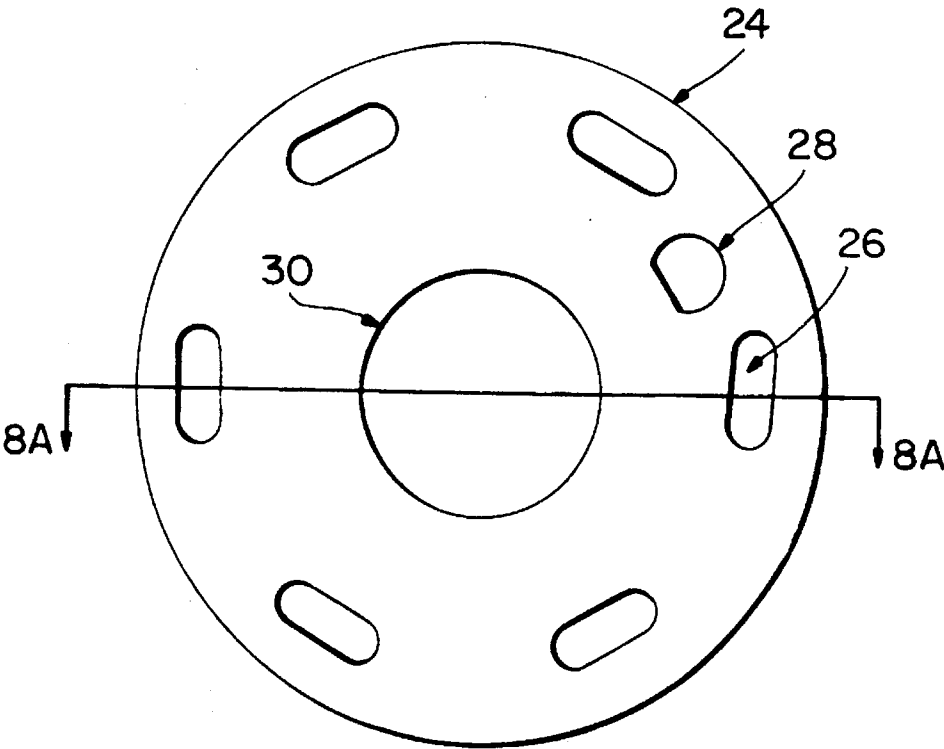
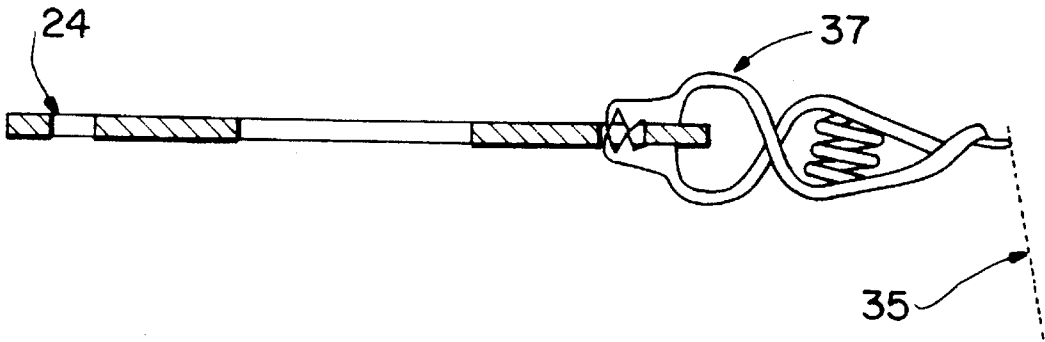


FIG. 8A



PORTABLE RAPIDLY ERECTABLE DISCONE ANTENNA

STATEMENT OF GOVERNMENTAL INTEREST

The Government has rights in this invention pursuant to Contract No. N00039-89-C-5301.

This is a continuation of application Ser. No. 08/388,126, filed on Feb. 13, 1995, now abandoned which is a continuation of Ser. No. 08/049,334, filed on Apr. 21, 1993, now abandoned.

BACKGROUND OF THE INVENTION

The present invention is a portable, rapidly erectable and easy to disassemble discone antenna for use in wide band, high frequency ground wave communication.

A study entitled "The Utility of High Frequency Ground Wave In a Distributed Communication System" by one of the inventors James R. Champion was described at a scientific conference Oct. 15, 1990 and was published in *Conference Proceedings C. P. 486, The Advisory Group for Aerospace R&D, Neuilly Sur Seine, France*, pp. 4-1 to 4-6, 1991. This reference does not describe the particular features of the invention relating to portability, ease of assembly and disassembly but deals mainly with its effectiveness as an antenna. (See paragraph 2.)

A discone antenna is described in "Three New Antenna Types and Their Applications", A. G. Kandoian, *Waves and Electrons*, 70 W-75 W, Feb, 1946. The benefits of grounding the antenna are mentioned on page 71 W.

Discone antennas are generally described in a scientific article entitled "Designing Discone Antennas", J. J. Nail, *Electronics*, Vol. 26, pp 167-169, Aug. 1953. The present antenna is constructed according to the basic relationships described in the article and illustrated in FIG. 1.

Neither of these two references discuss the portable feature of the instant invention.

U.S. Pat. No. 3,701,159 entitled "Discone Antenna", is an inverted discone antenna with the ground mat acting as the disc and the cone portion suspended from poles fixed in the ground. It is not useful for high frequency communications, is not portable and cannot be disassembled easily. (See abstract and paragraph bridging columns 1 and 2.)

U.S. Pat. No. 4,143,377 teaches a discone antenna variation wherein two discone antennae are used together, one mounted atop the other. (See abstract and FIG. 1). It is not portable and cannot be disassembled easily.

U.S. Pat. No. 4,918,460 describes a telescopic mast operating in conjunction with reels for winding sets of stays. The masts are useful to support antennas for mobile installations. (See abstract and column 1, paragraph 1.)

U.S. Pat. No. 3,189,906 is a conical antenna wherein the radiating elements serve to brace and support the antenna. This antenna can be adapted for quick assembly. (See column 2, lines 21-26.)

The following three patent references describe portable antennas not of the discone type.

U.S. Pat. No. 3,579,244 describes radiating elements made of flexible thin steel secured to a telescoping mast. Ground elements also made of the thin steel are secured to the mast in a plane perpendicular to the mast. (See abstract.)

Related patents U.S. 4,743,917 and U.S. Pat. No. 4,750,001 teach roll-out antennas wherein the antenna wire is wound onto a reel for transportation and storage. (See abstracts.)

OBJECTS OF THE INVENTION

It is an object of the present invention to produce a portable discone antenna.

Another object is to produce a discone antenna able to be easily and rapidly assembled and disassembled.

Still another object is to produce an discone antenna which, when disassembled, can be stored in a back pack and carried by one person.

It is also an object of the present invention to produce a robust, portable discone antenna able to be used for nuclear-survivable, non-fading, non-line-of-sight, high frequency ground wave communication.

SUMMARY OF THE INVENTION

This invention is an antenna wherein the conducting elements form a disc atop the small end of a cone with the plane of the disk perpendicular to the axis of the cone. The disc portion of the discone antenna has the aspect of a spoked wheel and is made of a plurality of telescoping linear elements each connected at its proximal end to a central hub. The linear elements are electrically tied together by attaching each element distal end to a wire formed into a circle. The connections to the hub and to the circular wire are detachable.

The cone portion of the discone antenna is made of a plurality of flexible wires connected at their proximal ends to the central hub and at their distal ends to the ground. A main feature of the invention is that the cone elements also serve as the support or guying means for the antenna. The connections to the hub and to the ground are detachable. The cone elements are connected to the ground in such a fashion that they are electrically isolated from the ground.

The central hub is supported by a mast. The disc portion and the cone portion of the central hub are electrically isolated from each other and from the mast.

The antenna is connected to a transceiver by a coaxial cable with the center wire connected to the disc portion and the outer conductor connected to the cone portion.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is cross sectional representation of the discone antenna and a corresponding table of required relationships of the various elements of the antenna.

FIG. 2 is a drawing of the top plate assembly of the discone antenna.

FIG. 3 is a drawing of the bottom plate of the discone antenna.

FIG. 4 is a sectional drawing showing details of the central hub.

FIG. 5 shows a telescoping element extended to its full length.

FIG. 6 is a plan view of the discone antenna embodying the invention showing a circular attachment to the ends of the telescoping elements.

FIG. 7 shows the swaged tubes of the mast disassembled.

FIG. 8, partially in section, illustrates one form of quick release between the conical wires and the bottom plate of the top plate assembly.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiment of the discone antenna of the present invention will first be described in reference to FIG.

1, wherein 1 is the disk and 2 is the cone. The outer conductor 4 of a coaxial cable 5 is connected to cone 2 of the antenna while the center wire 6 is connected to disk 1.

Also in FIG. 1, D represents the diameter of disk 1, C_{min} is the minimum diameter of cone 2, C_{max} is the maximum diameter of cone 2, S is the space between disk 1 and cone 2 and L is the length of the side of cone 2.

As discussed above, discone antennas generally are constructed according to parameters determined by relationships found in the Nail paper discussed above. These relationships are listed below in Table 1 and in FIG. 1. Note that all the parameters are related to the communication wave length λ .

$$L=(\lambda/4)\times 0.96 C_{max}$$

$$D=0.7 C_{max}$$

$$C_{min}=\leq L/22$$

$$S=0.3 C_{min}$$

As long as these parameters are met, a discone antenna may be constructed or tuned to be effective in a particular frequency range. The portable antenna of the invention is intended to be used for high frequency (HF) ground wave communication in the 20 to 30 MHz band range. A cut-off frequency of 18 MHz has been selected to provide good performance throughout the entire band. Using the relationships of Table 1 with $\lambda=18$ MHz produces the following, expressed in meters:

$$C_{max}=3.99$$

$$C_{min}=0.181$$

$$D=2.79$$

$$S=0.053$$

$$L=3.99$$

The disk 1 incorporates six telescoping elements each provided at the proximal end with a bulkhead connector and a coupling unit (not shown). A top plate assembly generally indicated at 8 in FIG. 2, comprises a circular plate 10 the top side of which is provided with six right angle SMA connectors 12. Each SMA connector is secured to the plate with screws 14 but also may be welded to the plate. Note that there is no requirement that SMA connectors be used; the only requirement is that the telescoping elements are quickly and easily attached to the connectors 12. For example, a press fit type coupling could be used.

One representative form of telescoping element is identified in FIG. 5 by the referenced numeral 11, with the individual segments shown extending between proximal and distal ends 11(a) and 11(b), respectively.

To assemble the disk, the bulkhead connectors of the telescoping elements are secured to the SMA connectors 12 with the coupling unit. The elements are telescopically extended to a length of approximately 1.40 m measured from the center of top plate 10. The distal ends of the extended telescoping elements are electrically connected by attachment to a wire 13. The wire 13, as shown in FIG. 6, is understood to form a closed circle having six points of attachment to plate 10 of top plate assembly 8. Alternatively, this attachment may be a cup shaped member attached to the wire and pushed onto the distal end 11(b) or by using an alligator clip, for example.

The center feeder wire 6 of coaxial cable 5 from a transceiver (not shown) passes through opening 18 and is attached to top plate 10 at point 40. Top plate 10 rests on the top of hollow, inverted cup shaped, cylindrical spacer 20

having a height equal to S, a bottom surface 20a and a closed end 20b. The locations of cylindrical inner surface 21 and the cylindrical outer surface 22 in relation to top plate 10 are shown in dotted lines. These features will be discussed more fully below in reference to FIG. 4.

FIG. 3 shows the bottom plate 24 which forms the top of cone 2 and C_{min} . Plate 24 is provided with six slots 26. The elements of cone 2, shown as length L in FIG. 1, are formed by retractable steel wires that unroll from their own cases (not shown) in a fashion similar to retractable measuring tapes. (When the antenna is disassembled, the steel wires are retracted into the cases through the action of a spring loaded reel.) The free end of the wire is attached to a battery clamp which fits into slot 26 and thus electrically connects the wire to bottom plate 24 and to the other five wires. Each wire case is provided with means such as a rope loop and a stake to fix the case to the ground or other surface and to electrically isolate the wire from the ground. For the cut-off frequency of 18 MHz, the cone radiating elements must be about 3.99 meters in length. Instead of wires as radiating elements, retractable metal tapes may be used. Although a slot and battery clamp connection is described any means to electrically connect the radiating elements to the bottom plate may be used.

A mast 32 passes through opening 30 in bottom plate 24 and extends into spacer 20 a distance sufficient to engage bottom surface 20a of spacer 20 in abutting supporting relationship. Opening 28 is provided with a bulkhead connector 36 through which passes coaxial cable 5 from the transceiver (not shown). The bulkhead connector 36 connects the outer conductor 4 of cable 5 to bottom plate 24 and thus to the cone radiating elements.

The section of coaxial cable 5 leading to bulkhead connector 36 is secured along the length of mast 32 by electrical tape. However, clips or VELCRO fasteners may also be used. Securing the cable to the mast avoids extraneous RF (radio frequency) fields from the antenna inducing undesirable currents in the cable.

The central hub of the discone antenna is generally indicated at 34 in FIG. 4. It comprises a top plate assembly 8, a hollow inverted cup shaped cylindrical spacer 20 and the bottom plate 24. The top plate assembly 8 is mounted on the flat closed end of spacer 20 and bottom plate 24 is mounted on the end of spacer 20 provided with the inverted cup. Spacer 20 is made of nonconducting material that electrically isolates the two metal plates 10 and 24 from each other and from mast 32. In the preferred embodiment, spacer 20 is made of a nonconducting phenolfiber material but other solid nonconductors such as wood may also be used.

In this preferred embodiment, spacer 20 is provided with a passage 38. This passage allows center wire 6 of coaxial cable 5 to be electrically connected to the center of top plate 10 at point 40.

Top plate 10 is fixed to spacer 20 by screws 14 and bottom plate 24 is fixed to spacer 20 by screws 42.

For ease in carrying, mast 32 is formed of a plurality of sections of swaged aluminum tubing 33 (shown disassembled in FIG. 7) but may be made of any number of sections, depending on the length L and packing requirements. The top of mast 32 is not fixed to cylindrical spacer 20 but is inserted into the spacer through opening 30 in bottom plate 20 to an extent that, when in supporting relationship to spacer 20, the end of the top section of mast 32 is separated from the bottom surface of top plate assembly 8 by the thickness of the closed end 20b of spacer 20. As shown in FIG. 4, the diameter of the tubular mast is such that it fits snugly into cylindrical cup of spacer 20. The bottom of mast

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32 rests on the ground and may be provided with a base consisting of a flat plate to provide stability during antenna assembly. Because of the thickness of spacer 20 at location 44, mast 32 does not come in contact with and is electrically insulated from top plate 10. Since the diameter of opening 30 in bottom plate 24 is slightly greater than the inner diameter of spacer 20, mast 32 does not contact bottom plate 24 and is electrically insulated from it.

To assemble the antenna, mast 32 is assembled from the swaged sections and its upper end is inserted into hole 30 of central hub 34. The flexible wires 35 (shown in FIG. 8), forming cone 2 are fixed by alligator clips 37, for example into slots 26 in bottom plate 24 of central hub 34 and are unreeled a length L (FIG. 1) from their cases. Each case is 15
staked to the ground or any other surface so that each flexible wire forms an angle in the range of 15°–45°, and preferably 30° with mast 32. The flexible wires are made taut and thus stabilize or guy the antenna. Disk 1 is assembled atop cone 2 by connecting the proximal ends of the telescoping linear elements to the central hub and the 20
distal ends to the circular wire. The linear elements are then extended to form a taut wagon wheel shaped structure. In this embodiment, the assembled antenna is approximately 3.5 meters tall.

To disassemble the antenna, the telescoping elements are 25
telescoped inwardly to reduce the length and are disconnected from the circular wire and the central hub. The flexible wires are disconnected from the central hub as well as from the ground or other surface and reeled into their individual cases. The mast is disconnected from the central hub and is pulled apart into its individual segments. When all 30
the parts have been disassembled, they can easily fit into a one foot wide by three foot deep sack.

Disassembled, the antenna can be carried in a back pack by an individual on foot and moved to another location. The exemplar created for the preferred embodiment weighs 35
approximately 7.5 lbs.

The invention described is not intended to be limited to the embodiments disclosed but includes modifications made within the true spirit and scope of the invention.

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We claim:

1. A central hub for a portable rapidly erectable discone antenna comprising:

a top plate assembly,

an inverted cup shaped cylindrical spacer provided with a flat closed end and an open end and having a cylindrical interior which terminates in a bottom surface;

a bottom plate;

a plurality of flexible wires; and wherein the top plate assembly is mounted on said flat closed end of said spacer and is provided with means to detachably connect a plurality of telescoping linear elements to the central hub; and

wherein said bottom plate is mounted on said open end of said spacer, and is provided with means for detachably connecting said flexible wires to the periphery of said bottom plate and is provided with a central opening having a diameter greater than the diameter of the cylindrical interior; and

a supporting mast inserted through the central opening in said bottom plate and extending into the cylindrical interior of said spacer a distance sufficient to come into direct and removeable engagement with the bottom surface of said cylindrical interior of said spacer in abutting supporting relationship.

2. A central hub according to claim 1, wherein said mast is of metallic construction the spacer electrically isolates the top plate assembly, the bottom plate and the mast from one another.

3. A central hub according to claim 1, wherein the top plate assembly is provided with means to detachably connect to a plurality of telescoping linear elements to form a disk portion of the discone antenna, and the bottom plate is provided with means to detachably connect to said plurality of flexible wires to form a cone portion of the discone antenna.

* * * * *

A VHF/UHF Discone Antenna

A practical antenna for 144, 222 and 440 MHz and everything in between!

Amateur Radio will surely become more involved in Homeland Security communications. That will mean that the need for multiband operations on VHF and UHF will be more than a desired option; it will be a requirement. Likewise, we will likely have a need to monitor radio communications of other services that operate between and above our VHF/UHF frequencies. Amateurs could also be called upon to provide technical support to emergency services if they catastrophically lose all outside antennas. All of these situations make the Discone antenna a reliable design and a great option for Homeland Security as well as general amateur use.

This antenna design is not original with me. The original version appeared in a December 1978 *QST* article written by David Geiser, WA2ANU (now W5IXM)¹ [The earliest professional reference to the Discone appears in a 1946 paper by A. G. Kandonian, then of Federal Telephone and Radio Laboratories. Mr Kandonian appears to be the first to have coupled a disc with a cone.² The earliest published amateur reference is a 1949 *CQ* article by J. M. Boyer, W6UYH.³—Ed.]

I became familiar with it while stationed in Germany in 1979 as a US Signal Corps officer. We needed an antenna to cover several VHF frequencies, but we could not get one through the military supply system. I remembered this antenna design in *QST* and decided to build one for my unit's use. It worked so well that I wound up building several of them. Today's serious need makes this antenna an excellent multi-frequency radiator and an option to be aware of.

The Discone Advantage

Discones have some unusual operational

characteristics that can be distinct advantages as Homeland Security communications antennas. The antenna radiates like a quarter wave vertical above a ground plane. While there is little gain, the antenna shows extremely wide bandwidth—a major asset. Discone antennas behave like high-pass filters [or impedance transformers, coupling to free space.—Ed.] in that, *above* a designed cutoff frequency, the antenna radiates well. *Below* that cutoff frequency the SWR rises sharply and the antenna ceases to function. Above the cutoff frequency, the SWR can remain acceptable for up to 10 times that frequency. This means a Discone designed for a lower-end frequency of 144 MHz will operate at all frequencies up to and well past 450 MHz while maintaining a 2:1 SWR. [Kandonian presents data that shows the SWR to be about 3:1 at the cutoff frequency and rapidly approaching a value of 1.3:1 at 50% above the cutoff frequency, where the cutoff frequency is 200 MHz.⁴ It appears best, therefore, to design a VHF-UHF Discone for a low-end cutoff frequency slightly below the operating frequency. The design formula in Figure 1 reflects that goal.—Ed.]

Geiser commented that his design worked at 1.3 GHz with a 5:1 SWR. While I haven't tried them at 1.3 GHz, the antennas I built for 144 to 444 MHz all had SWRs at or below 2:1, across that range. For Homeland Security operations this means that one antenna can transceive on the VHF/UHF amateur bands and also receive law enforcement, fire, EMS, government, military and other emergency service frequencies. The antenna could even be put into emergency backup service by those agencies.

Construction

Simply stated, a Discone looks like an inverted cone with a round disc placed

on its top and insulated from the cone. Amateur ingenuity will quickly bring to mind several ways one could construct such an antenna.

My first *test* antenna in 1979 was constructed not of metal, but from very heavy cardboard covered with heavy aluminum foil, appropriated from the military "mess hall." It worked like a charm and wound up sitting on the attic rafters of a German building for several years with good results. So much for the *test* model!

Geiser's design used "hardware cloth" or very stiff galvanized steel "chicken wire" that is manufactured as a ¼ inch square mesh. This design is based on the original version, but updated. This material does not need a lot of support if you intend to place the antenna inside an attic, out of the wind and weather. For outside use, a wood or PVC "tree" can be placed inside the antenna for rigidity and support. Here is how to do it.

Lay out a 5 foot long length of hardware cloth. Tack the corners down so it won't roll up. Use a felt tip marker pen to draw the cone and disc designs. Using a heavy metal shear, *carefully* cut out these antenna elements. Heavy gloves are recommended to protect hands from the sharp wire edges, which can inflict painful cuts. Fold the wire cloth into the cone shape. The height and diameter of the cone are about the same, about 110% of a ¼ wavelength at the lowest operating frequency, according to Geiser. The diameter of the disc is about 67% of the same parameter. Aluminum ground wire or nuts and bolts can hold the edges together to start. Some of the edge wires can be folded into hooks to give added strength to the seam. Use a heavy soldering iron to spot-solder the wire seam together. Figure 1 shows the general construction technique for the antenna, together with design formulas.

¹Notes appear on page 41.

To feed the antenna, an inverted SO-239 coaxial connector can be used to screw or solder the top of the cone to the connector's mounting flange and then solder the top disc to the center conductor. I prefer to solder the cable directly to the antenna and not use a coax connector. If you use a 1½ inch × 3 foot long PVC pipe as the center support, the pipe can be pushed through the cone and out the small end. The hardware cloth can then be screwed around its top lip. A small hose clamp can work well here, if you desire.

Run the coax up the PVC pipe and out the top. Notch the pipe end to let the shield rest in the notch and solder the shield to the top of the cone. The center conductor of the coax should then stand straight up. Drill a small hole in the center of a 3 or 4 inch plastic disc or square. (I used a PVC coaster.) Place it on top of the PVC pipe and run the center wire of the coax through the hole. Using PVC cement, glue this PVC disc to top of the PVC pipe. Solder the center conductor of the coax to the center of the wire disc. Center the hardware cloth disc on the plastic disc and attach it with several screws. That's it.

Options for construction material and technique are as varied as one can imagine. For the cone and disc, copper window screen can be used with wood strips for inside cone support. For larger antennas, you might consider self-supporting wire for the cone and disc rather than the screen material. I have seen very large discone antennas for the HF spectrum and they looked like string lights on a pole at Christmas. Now there's a thought!

On The Air

The VHF/UHF Discone is a lot more forgiving of construction techniques than are Yagi or quad antennas. Initial tests will surely be successful if you get the antenna in the clear and elevate it. For a first test, I had my antenna on my desk. I got a 59 report from a station about 3 miles away. Not spectacular, but I was inside the house with the antenna on a metal desk at ground level and it was being fed less than 10 W of RF. Once I put it up at 50 feet it worked well on every VHF/UHF frequency I tried. The SWR remained below 2:1 on both 146 MHz and 440 MHz.

Any good commercial $\frac{5}{8}$ -wave antenna, small Yagi or homebrew VHF/UHF quad can beat this antenna at gain on a given design frequency, but none of these will have the gain-bandwidth product across the VHF/UHF spectrum that this performer has. If you need a high bandwidth, easy to construct antenna that's ideal for emergency communications, the Discone is worth a look.

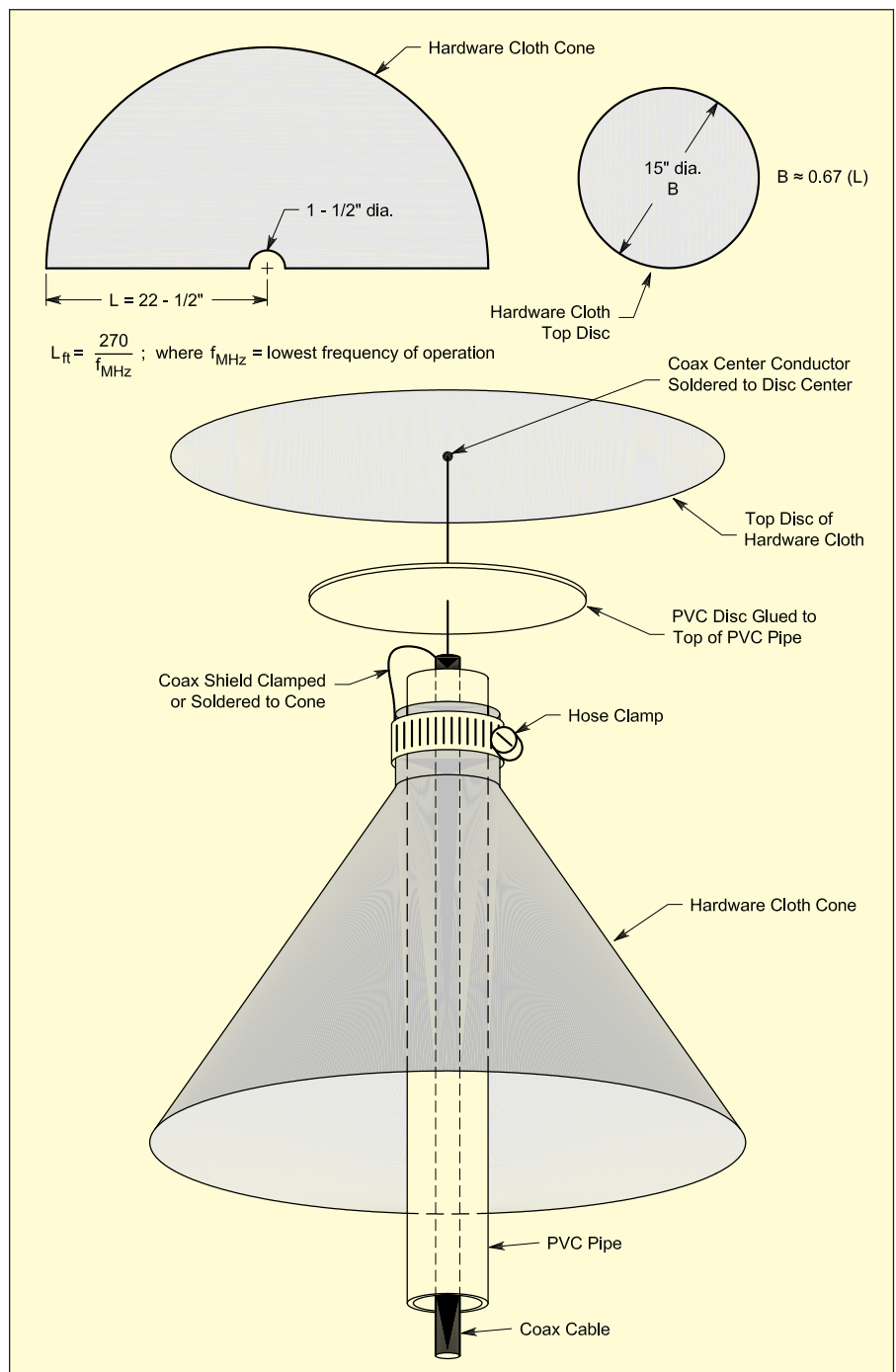


Figure 1—Construction of the hardware-cloth discone antenna.

Notes

¹D. Geiser, WA2ANU, "An Inexpensive Multi-band VHF Antenna," *QST*, Dec 1978, pp 28-29.

²A. G. Kandonian, "Three New Antenna Types and Their Applications," *Proceedings of the I.R.E.*, Vol 34, Nr 2, Feb 1946, pp 70-75.

³J. M. Boyer, W6UYH, "Discone—40 to 500 Mc Skywire," *CQ*, Jul 1949, p 11.

⁴See note 2.

Bob Patterson, K5DZE, is an Amateur Extra class amateur and Life Member of ARRL with over 45 years of ham radio experience. He has operated across the country as well as overseas, where he has held the call signs HL9EZ and DA1EZ. Bob spent five years with

the US Marines and 25 years with the US Army, retiring as a Lt Colonel. He holds a BS in Professional Aviation from Louisiana Tech University. Bob is currently vice president of Finance and Administration for Central Bible College in Springfield, Missouri. He is the faculty advisor and club trustee of the CBC ARC, W5CBC, which won the ARRL Achievement Award 2000 as top college/school club in the US. He is an active volunteer examiner and emergency coordinator, and is a former DEC. His operating interests include QRP, CW and DX. You can contact the author at 1280 W Burntwood St, Springfield, MO 65803; k5dzc@arrl.net. **QST**

All About the Discone Antenna: Antenna of Mysterious Origin and Superb Broadband Performance

Learn about the development, history and some applications of a discone antenna.

Steve Stearns, K6OIK

“**T**he frequency bandwidths demanded by high-definition television have considerable range...” With these prescient words, Philip S. Carter of RCA opened a 1939 paper that compared a variety of antennas for the emerging field of “high-definition” television. Carter showed conclusively that conical antennas held distinct advantages over dipoles and folded dipoles when it comes to broadband performance. Today, conical antennas are making a comeback for broadband applications such as digital television and UWB (ultra-wideband) or impulse radio. Stacked arrays of bowties and biconical dipoles are gradually displacing traditional mainstay antennas such as Yagis and log-periodics for the rooftop reception of digital television (DTV). One conical antenna, long popular among scanner hobbyists, the discone, has been described in previous articles in Amateur Radio magazines and books. The story has never been told fully, however. This article explains the history and theory of the discone, corrects some common misunderstandings, and presents an *EZNEC* model for a 0.6-octave discone that readers may copy and scale to their favorite frequency bands.

Conical antennas, and the discone in particular, have an obscure but fascinating history. Sergei Alexander Schelkunoff, at Bell Labs, was a titan of antenna theory in the early to mid 20th Century. In 1941, Schelkunoff published a major paper in the *Proceedings of the IRE*, which, among other things, analyzed the symmetric biconical dipole and showed that many other antennas can be analyzed

as extensions of it.¹ The discone antenna (Figure 1) is one such extension, in which the biconical dipole is asymmetric, one cone’s angle being 90°, which gives a flat disk of radius equal to the cone length. Two years later, in 1943, Armig Kandoian at the Federal Telephone and Radio Corporation applied for a pat-

¹Notes appear on page 43.

ent on the discone antenna. Kandoian’s novel or inventive element was apparently that the antenna could be encased in a radome, making it suitable for aircraft, not that it used a cone or disk per se, those ideas being obvious in view of Schelkunoff’s prior work. The patent was granted in 1945, whereupon Kandoian and his colleagues, Sichak, Felsenheld, and Nail, at the newly renamed Federal Telecommunica-

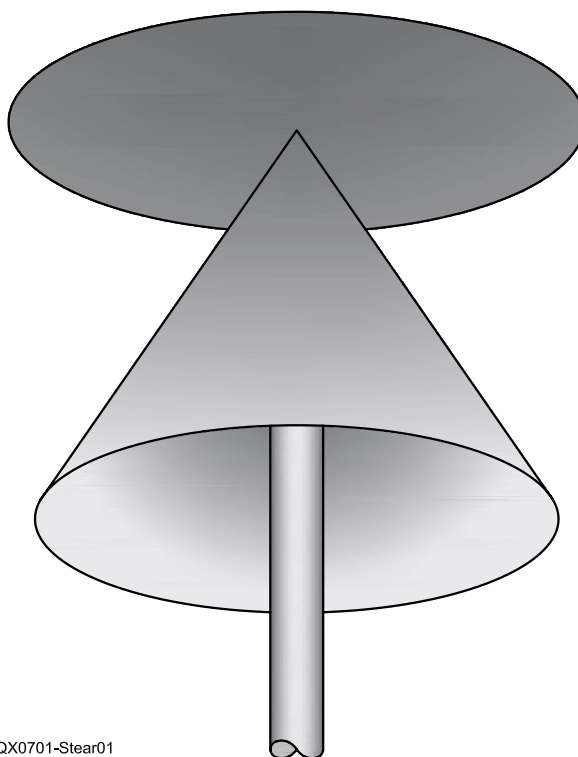


Figure 1 — This illustration shows a home-made discone for 2.4-GHz WiFi use. See www.spaziolink.com/wi-fi.

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PO Box 4917
Mountain View, CA 94040-0917
k6oik@arrl.net

tion Laboratories, a subsidiary of ITT, began publicizing the antenna in a series of articles in various journals from 1946 to 1953.

In 1952, Schelkunoff published the book *Advanced Antenna Theory*, which gave a comprehensive analysis of the asymmetric biconical dipole in which the angles and lengths of both cones are arbitrary. The discone appeared on page 93 as a special case. Engineering studies of the discone followed shortly thereafter by Nail at the Federal Telecommunication Laboratories and by Crowley and Marsh at Ohio State University. Many variations on the basic discone have appeared since, having such features as multiple cones, multiple disks, meander lines for the cone, and mechanical tuning devices.

Radio Amateurs, meanwhile, had noticed this interesting antenna. A construction article appeared in *CQ* in 1949. More construction articles appeared since then, and are noted at the end of this article. Given such interest, it is surprising that amateur antenna modelers have largely overlooked this antenna. This article corrects that oversight by presenting an *EZNEC* model for a discone that readers may copy, modify, or scale to their favorite bands.

Conical antennas consisting of a single cone fed at its apex against an infinite ground plane are often called “monocoines” or less often “unipoles.” If the infinite ground plane is replaced by one that is finite and circular, the antenna is called a “discone.” A discone can also be thought of as an asymmetric biconical dipole in which one cone’s angle is 90° (measured from its axis), so it opens to become a flat disk. The impedance of a discone depends on frequency and three geometric variables: the cone’s angle, slant length (measured along the

side of the cone), and the radius of the ground plane disk. Feed line SWR depends additionally on the line’s characteristic impedance. A discone is not a frequency independent antenna, although this is a common misconception. Rather, a discone behaves more like a fat dipole. Its feed point resistance and reactance vary with frequency, although not through the extremes of a dipole.

Discones are used for broadband operation at frequencies above their first resonance. Manufacturer’s data for two popular VHF/UHF discones, the AOR DA3000 and RadioShack 20-043 are shown in Figures 2 and 3 as graphs of return loss versus frequency. The vertical scale of the AOR curve is 10 dB/division; the scale of the RadioShack curve is unspecified. The key feature is that the curves are scalloped. The SWR cycles between high and low as frequency is varied. Receiving is possible on any frequency, but transmitting is best done in the SWR valleys. A good design will keep the SWR peaks below a design limit and position the valleys to coincide with desired transmit frequencies.

There are, broadly speaking, two methods for analyzing antennas that don’t require construction and measurement. The first method is mathematical analysis, and the second is numerical antenna modeling. The former was the only method available before computers were invented. Antennas were analyzed mathematically by “normal mode theory” or by solving integral equations. In this article, we’ll use a formula developed by Schelkunoff for the feed point impedance of a finite cone over an infinite ground plane, derived from spherical mode theory. The formula allows us to quickly determine the best length and angle

for a cone depending on design impedance and bandwidth. More exact formulas for when the disk radius is finite are in the engineering literature. We’ll use an *EZNEC* model when analyzing such cases.

In his 1941 paper, Schelkunoff showed that the feed point impedance of many antennas, including the conical monopole over a ground plane, can be represented as terminated transmission lines one-quarter wave shorter than the length of the antenna:

$$Z_m = Z_0 \frac{Z_m + jZ_0 \tan\left(k\ell - \frac{\pi}{2}\right)}{Z_0 + jZ_m \tan\left(k\ell - \frac{\pi}{2}\right)} \quad (\text{Eq 1})$$

For a conical monopole of angle θ , measured from axis, the characteristic impedance Z_0 is given by:

$$Z_0 = \frac{\eta}{2\pi} \ln \cot\left(\frac{\theta}{2}\right) \quad (\text{Eq 2})$$

The terminating impedance $Z_m = R_m + jX_m$ is the radiation impedance referenced to the current maximum on the antenna. Schelkunoff gave general formulas for the real and imaginary parts of Z_m for all cone angles, but he also gave the formulas for small cone angles in Equation 3 below, where k is the wavenumber $2\pi/\lambda$ and η is the characteristic impedance of free space equal to $\mu_0 c$, the speed of light times the magnetic permeability of free space, or 376.73 Ω . (It would be exactly 120 π Ω if light would cooperate and travel at exactly 300 million meters per second.) Other symbols in the formulas are Euler’s constant, $C = 0.5772156649\dots$ and

$$R_m = \frac{\eta}{4\pi} \left\{ C + \ln(2k\ell) - \text{Ci}(2k\ell) + \frac{1}{2} \sin(2k\ell) [\text{Si}(4k\ell) - 2\text{Si}(2k\ell)] + \frac{1}{2} \cos(2k\ell) [C + \ln(k\ell) + \text{Ci}(4k\ell) - 2\text{Ci}(2k\ell)] \right\} \quad (\text{Eq 3})$$

$$X_m = \frac{\eta}{4\pi} \left\{ \text{Si}(2k\ell) - \frac{1}{2} \sin(2k\ell) [C + \ln(k\ell) - \text{Ci}(4k\ell)] - \frac{1}{2} \cos(2k\ell) \text{Si}(4k\ell) \right\}$$

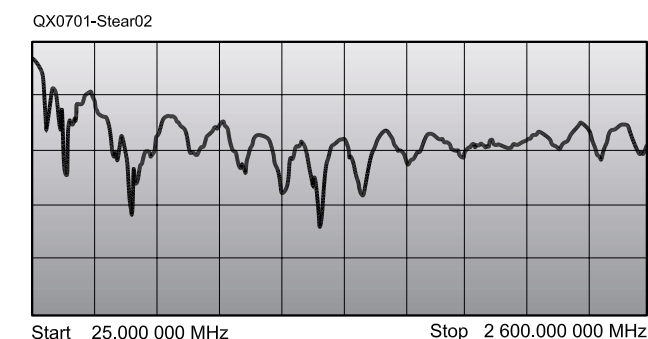


Figure 2 — Return loss of AOR DA3000 discone antenna.

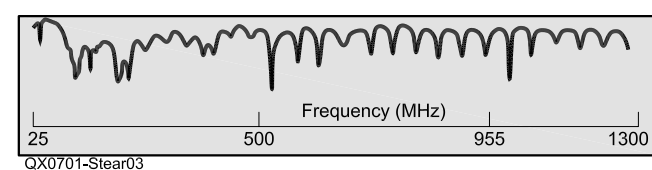


Figure 3 — Return loss of RadioShack 20-043 discone antenna.

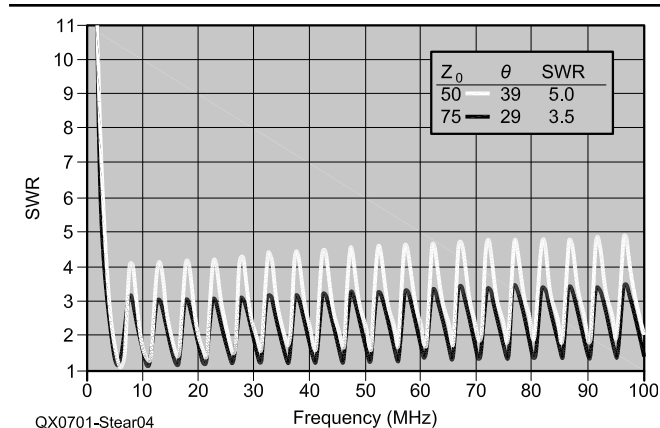


Figure 4 — Computed SWR (at 50 and 75 Ω) of two 100-foot cones.

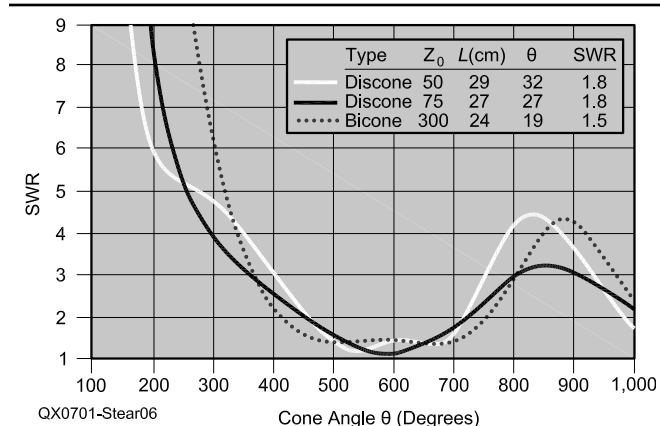


Figure 6 — Predicted SWR of three antennas optimized for UHF TV.

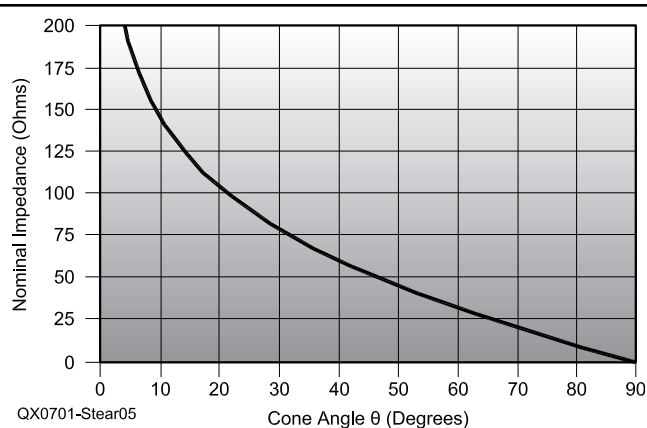


Figure 5 — Nominal monocone and discone impedance versus cone angle.

the sine and cosine-integral functions $\text{Si}(x)$ and $\text{Ci}(x)$, which we won't explain here.

Schelkunoff's asymptotic formula isn't numerically accurate for discons having large cone angles or finite disk radii. The formula, however, does reveal general trends and interesting design trades. More accurate formulas for general discons and biconical dipoles or "bicones" were developed by Hahn and Fikioris, and most recently by Samaddar and Mokole.²

For broadband operation, the best cone angle depends on bandwidth. Given a frequency band from f_1 to f_2 , the optimum cone angle decreases as the ratio f_2/f_1 increases. For a nominal 50- Ω antenna, as the design bandwidth increases from one to five octaves, the optimum cone angle decreases from 47° to 39°, and the peak SWR creeps up. In addition, as the feed point design impedance increases, the optimum cone angle decreases. An interesting implication pursued in some designs is that the cone should be curved instead of flat sided. Our interest here is flat-sided cones.

Wires										
Wire Other										
Coord Entry Mode Preserve Connections										
Wires										
No.	End 1			Conn	End 2			Conn	Diameter	Segs
	X (mm)	Y (mm)	Z (mm)		X (mm)	Y (mm)	Z (mm)		(mm)	
1	0	0	0	W2E1	0	88.2557	0		2.72211	8
2	0	0	0	W3E1	-33.774	81.5376	0		2.72211	8
3	0	0	0	W4E1	-62.4062	62.4062	0		2.72211	8
4	0	0	0	W5E1	-81.5376	33.774	0		2.72211	8
5	0	0	0	W6E1	-88.2557	-7.71556E-06	0		2.72211	8
6	0	0	0	W7E1	-81.5376	-33.774	0		2.72211	8
7	0	0	0	W8E1	-62.4062	-62.4062	0		2.72211	8
8	0	0	0	W9E1	-33.774	-81.5376	0		2.72211	8
9	0	0	0	W10E1	1.05244E-06	-88.2557	0		2.72211	8
10	0	0	0	W11E1	33.774	-81.5376	0		2.72211	8
11	0	0	0	W12E1	62.4062	-62.4062	0		2.72211	8
12	0	0	0	W13E1	81.5376	-33.774	0		2.72211	8
13	0	0	0	W14E1	88.2557	1.54311E-05	0		2.72211	8
14	0	0	0	W15E1	81.5376	33.774	0		2.72211	8
15	0	0	0	W16E1	62.4062	62.4062	0		2.72211	8
16	0	0	0	W33E1	33.774	81.5376	0		2.72211	8
17	0	0	0	W18E1	0	122.577	251.571		2.72211	23
18	0	0	11	W19E1	-46.9082	113.246	251.571		2.72211	23
19	0	0	11	W20E1	-86.675	86.675	251.571		2.72211	23
20	0	0	11	W21E1	-113.246	46.9082	251.571		2.72211	23
21	0	0	11	W22E1	-122.577	-1.0716E-05	251.571		2.72211	23
22	0	0	11	W23E1	-113.246	-46.9082	251.571		2.72211	23
23	0	0	11	W24E1	-86.675	-86.675	251.571		2.72211	23
24	0	0	11	W25E1	-46.9082	-113.246	251.571		2.72211	23
25	0	0	11	W26E1	1.46172E-06	-122.577	251.571		2.72211	23
26	0	0	11	W27E1	46.9082	-113.246	251.571		2.72211	23
27	0	0	11	W28E1	86.675	-86.675	251.571		2.72211	23
28	0	0	11	W29E1	113.246	-46.9082	251.571		2.72211	23
29	0	0	11	W30E1	122.577	2.14321E-05	251.571		2.72211	23
30	0	0	11	W31E1	113.246	46.9082	251.571		2.72211	23
31	0	0	11	W32E1	86.675	86.675	251.571		2.72211	23
32	0	0	11	W33E2	46.9082	113.246	251.571		2.72211	23
33	0	0	0	W1E1	0	0	11	W17E1	2.72211	1

Figure 7 — Wire table of an EZNEC discone model.

Figure 4 shows SWR curves calculated from Schelkunoff's formula for two 100-foot cones over infinite ground planes. The cone angle and length have been optimized for five-octave operation at both 50 and 75 Ω . Now, we can use an antenna modeling program to get better accuracy with less effort. Nonetheless, I found the best cone angles for each feed point impedance in a five-octave band with a single command to Microsoft *Excel*'s solver tool and 60 seconds of patience. Doing the same optimization in *EZNEC* would have taken days if *EZNEC* had an optimizer — which it doesn't, unfortunately.

An approximate formula for the best cone angle for a given feed point design impedance is obtained from the characteristic impedance formula above.

$$\theta = 2 \tan^{-1} \exp\left(\frac{-Z_0}{60}\right) \quad (\text{Eq 4})$$

Figure 5 illustrates the relation between θ and Z_0 given by this approximation. The predicted angle is good for design bandwidths up to two octaves but should be reduced if the design bandwidth is greater.

There are a lot of different ideas about the proper shape of a discone. Typing "discone" into Google Images reveals a variety of shapes. A common error appears to be making the disk too small and the cone too long. Using a computer, one can jointly optimize a cone's angle, slant length, and disk radius. Increasing the disk radius while simultaneously decreasing the cone's slant length is akin to sliding a feed point along an off-center-fed (OCF) dipole. This interpretation becomes exact if we regard the discone as an OCF biconical dipole with one cone's angle being 90°. Computer modeling reveals the best geometry for a given design impedance and band of operation, as will be shown below.

The procedure for designing a discone for transmitting has one extra step. The slant

length is adjusted to put the SWR valleys on the desired transmit frequencies. Alternatively, an SWR valley can be shifted to a transmit frequency by using a mechanical tuning scheme such as those of McNamara or Rappaport.

When constructing a discone, the cone and ground plane can be made from rods or sheet metal as illustrated in Figure 1. When using rods, at least eight should be used. The AOR DA3000 uses 16, while the Diamond D-130J and RadioShack 20-043 use eight. You can adjust the impedance by bending the rods in or out. This is an advantage of rod construction.

Example

As an example, we'll consider a discone for receiving UHF TV channels 14 through 53. The frequency range is 470 MHz to 710 MHz. We set the discone's first resonance at a frequency below 470 MHz because, as shown in Figure 4, the SWR shoots up below the first resonance. Making the antenna too small incurs a big penalty.

A rule of thumb is to set the first resonant frequency at 0.7 times the lowest operating frequency. In this example, that comes out

to 329 MHz or a wavelength of 91 cm. The disk radius plus cone slant length should equal half of this number or 46 cm. Now, you could allocate this length equally to the disk radius and cone slant length, making them both 23 cm. This may not be the best way to divide the length, however. Nail suggests that for a 50- Ω design, the ratio of radius to cone length should be:

$$\frac{R}{L} = 0.72 \times \sin\theta \quad (\text{Eq 5})$$

which gives $R/L = 0.36$ or the ratio $R:L = 26:74$ for a cone angle of $\theta = 30^\circ$. An antenna modeling program can be used to confirm this ratio or to find a better ratio for a different design impedance. You can vary the proportions: 10:90, 20:80, 30:70, 40:60, 50:50 and so on, and compute an SWR sweep for each combination to find what ratio gives the smallest peak SWR over the band of interest.

Let's consider the UHF TV antenna example. To keep things simple, we'll let the disk be an infinite ground plane and use Schelkunoff's asymptotic formula; in practice, we'd use *EZNEC* and include disk

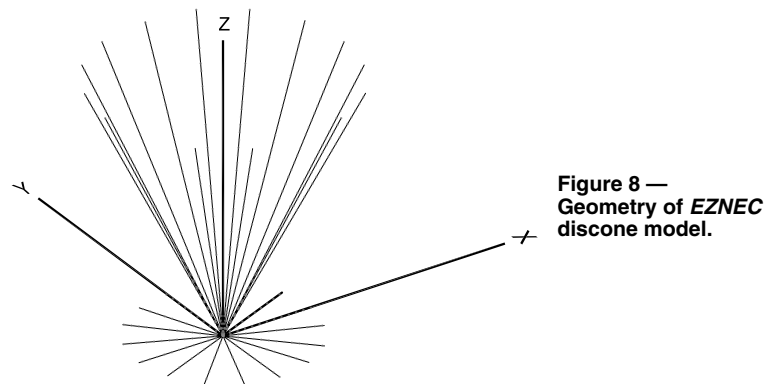
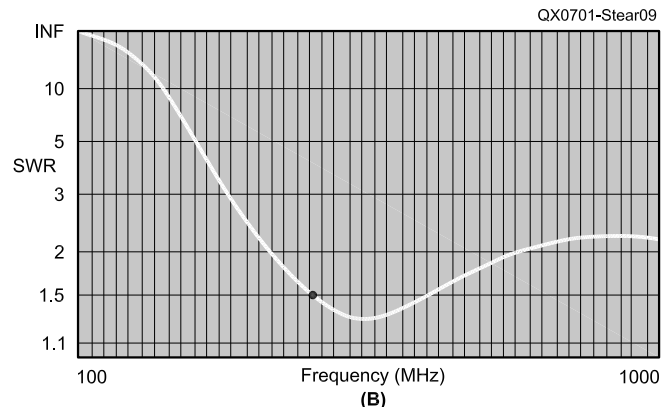
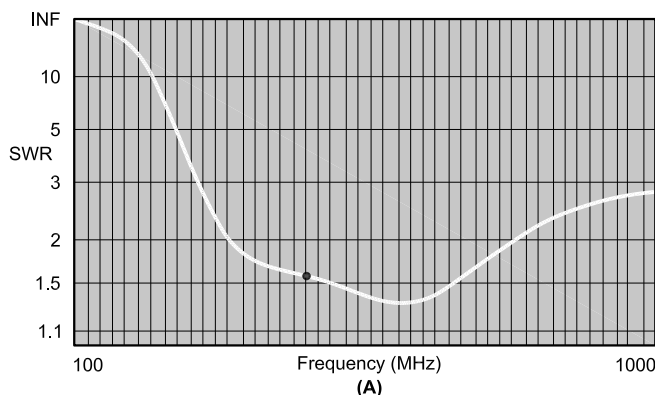


Figure 8 — Geometry of *EZNEC* discone model.

QX0701-Stear08



QX0701-Stear09

Figure 9 — SWR sweeps at (A) 50 Ω , and (B) 75 Ω ; the marker is at 460 MHz.

radius as a variable. The goal is to find the cone angle and slant length that together minimize the maximum SWR between 470 MHz and 710 MHz. We'll find design dimensions for 50 and 75 Ω discones and a 300 Ω biconical dipole. A biconical dipole has a balanced feed point. When designing television antennas having balanced feed points, it is customary to make the feed point 300 Ω because this permits using both 300- Ω balanced twin lead and 75- Ω coaxial line with a 4:1 current balun.

Numerical optimization quickly finds the best lengths and cone angles. The optimum lengths are 29, 27, and 24 cm, with cone angles of 32°, 27°, and 19° respectively for 50 and 75- Ω discones and a 300- Ω bicone. Notice that the lengths are greater than those given by the rule of thumb. The reason is that the design bandwidth is narrow enough that lengthening the antenna moves an SWR valley down to fit the band. A more revealing explanation will be given shortly on a Smith Chart. Figure 6 shows the predicted results.

For a 75- Ω design impedance, the best combination of cone angle and length were found to be 27° and 27 cm. The predicted SWR is the darker curve in Figure 6. The maximum SWR between 470 and 710 MHz is predicted to be 1.82.

At this point we are ready to consider the effect of a finite disk radius. We'll check the theoretical predictions by using an *EZNEC* antenna model that includes a finite disk having Nail's recommended radius.

$$R = L \times 0.72 \times \sin \theta \quad (\text{Eq } 6)$$

$$R = 27 \times 0.72 \times \sin 27^\circ = 27 \times 0.72 \times 0.4540 = 8.8 \text{ cm}$$

The discone model's wire table and geometry are shown in Figures 7 and 8. The model was created easily by defining two wires as prototypes for the disk and cone, and then

using *EZNEC*'s radial tool to complete the model. Wire 1 is the prototype wire for the disk. Wires 2 through 16 were created by *EZNEC*. Similarly, Wire 17 is the prototype wire for the cone, and Wires 18 through 32 were created by *EZNEC*. It's convenient to think of cone and disk wires as being grouped into 16 pairs, with 31 segments allocated to each pair. Segment lengths are made nearly equal by allocating 25% of the segments to the disk and 75% to the cone. Disk wires, therefore, have 8 segments, and cone wires have 23 segments. This gives segment lengths of 11 mm for the disk and 11.7 mm for the cone wires. The apex of the cone was offset by 11 mm from the plane of the disk to make room for a single-segment source wire, which is Wire 33. The total number of segments in the model is 497, and the segment size is under $\lambda/25$ up to 1 GHz, which is well above the upper band limit of 710 MHz.

Figure 9 shows the SWR predicted by *EZNEC* for 50 and 75- Ω reference impedances. The graphs' vertical scales are nonlinear in SWR but linear in reflection coefficient magnitude. Allowing for graph distortion created by the nonlinear scale, the 75- Ω SWR curve on the right can be compared to that for the 75- Ω conical monopole shown in Figure 6 (darker curve) which was computed from Schelkunoff's asymptotic formula. The two curves are highly similar in both shape and value. It's clear that the dimensions obtained by optimizing Schelkunoff's formula are quite good, but there's still room for improvement. At this point one might choose to either build and test the antenna with the current dimensions or refine the *EZNEC* model.

It is noted that the model performs well as a 50- Ω antenna as shown in the left curve of Figure 9A. The computed SWR is 1.54 and 1.58 at the band edges and achieves a minimum of 1.30 at 610 MHz. Although not

explicitly optimized for 50 Ω , the dimensions are fairly good for that impedance too. This is not mere coincidence but a consequence using Nail's recommended disk size, which is for a 50- Ω design, rather than a 75- Ω design.

EZNEC's 500-segment restriction limits the bandwidth for which it can be used. A minimal NEC model would have eight wires for the cone and eight wires for the disk. If the length of each wire is a quarter wavelength or $\lambda/4$ at the lowest frequency f_1 , then the total length of all 16 wires is $8 \lambda_1$. The segment length should be no greater than $\lambda_2/20$ where f_2 is the highest frequency. The number of segments, obtained by dividing the segment length into the total length, is $80 \lambda_1/\lambda_2$. Because *EZNEC* can handle at most 500 segments, the frequency ratio cannot exceed $f_2/f_1 = 500/80 = 6.25$, or 2.6 octaves. So, very broadband design should be done with a modeling program that can handle more than 500 segments, at least $80 f_2/f_1$ segments.

It's always a good idea to check whether a simple impedance matching network can improve the match over the band. The first step when designing a matching network is to plot the antenna impedance data on a Smith Chart. We'll use the impedance data that *EZNEC* computed. *EZNEC*'s frequency sweep feature allows the option of creating output data files for *MicroSmith* or *winSMITH*. It's best to choose *MicroSmith* to avoid *winSMITH*'s limit to 15 frequencies. *EZNEC* puts complex reflection coefficient (scattering parameter S_{11}) data in a .GAM text file. It should be opened with Microsoft Word, where it can be manipulated into a standard format for whatever EDA program you use, such as *ARRL Radio Designer*, Ansoft *Serenade SV* (featured in January 2001 *QST*), Agilent *ADS*, AWR *Microwave Office*, *RFSim99*, or even good old *SPICE*. I have found that Ansoft *Serenade SV* has the best capabilities for the money.

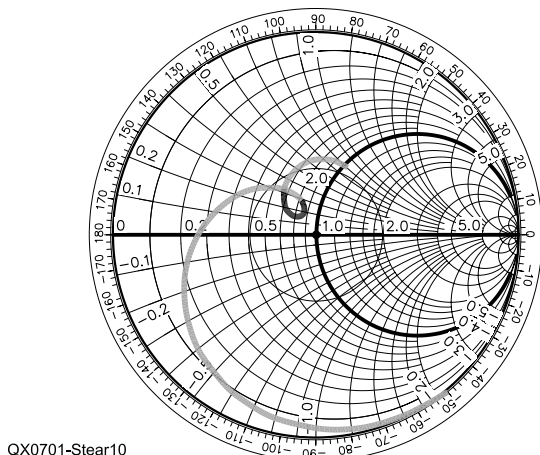


Figure 10 — Discone impedance on 75 Ω Smith Chart; UHF TV band highlighted with a darker band.

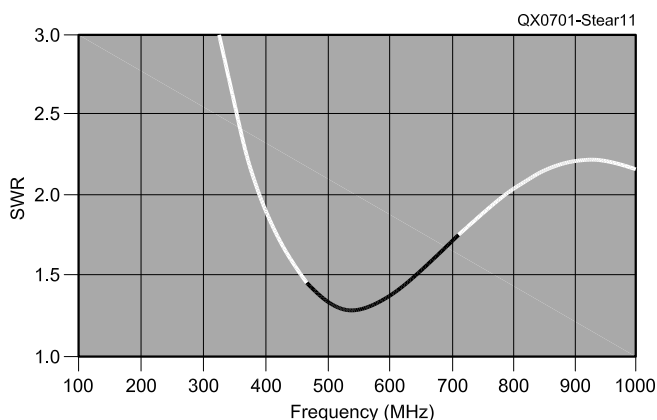


Figure 11 —SWR of unmatched discone (referenced to 75 Ω).

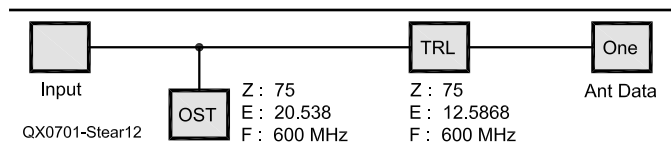


Figure 12 — An open stub impedance-matching network for 75 Ω .

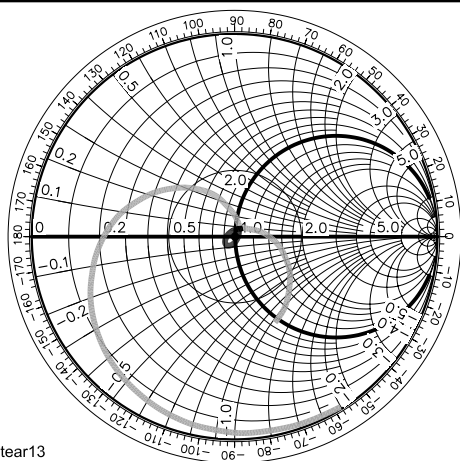


Figure 14 — The matching stub reduces the maximum SWR from 1.28 to 1.12 on the UHF TV band.

Table 1

An EZNEC .GAM Date Table Converted to .FLP Format for Analysis by Serenade

antdata	100MHz	1000MHz	91	50	S
EZNEC data for UHF TV discone antenna created on 2/28/2006.					
100MHz	0.9957904	-34.86269			
110MHz	0.9935989	-38.95737			
120MHz	0.9905544	-43.24265			
980MHz	0.4676752	42.40280			
990MHz	0.4689465	41.08628			
1000MHz	0.4697061	39.79027			

The .GAM file is formatted to Ansoft's .FLP format within Microsoft Word in a few simple steps. First, delete the header line, leaving only the data lines. Next, use the text-to-table converter in Word to put the data into a four column table. Cut the contents of columns two and three and paste to columns three and four, leaving column two empty. Type the frequency unit "MHz" as the first entry in Column two, and paste it into all cells down the column. Next, do a table-to-text conversion, specifying a "space" character as the delimiter. Finally, remove the space between the frequency number and its unit by a global replacement of "[space]M" with "M." The data lines are now finished. Just add two header lines before the data lines, making sure to specify "50 S" on the first line to indicate that the data is scattering parameter data referenced to 50 Ω . This is the same convention

that EZNEC used when making the output data. Finally, save the file as a text file with the .FLP name extension to a Serenade project folder. The file should look like Table 1

Once the .FLP file has been saved, we open Serenade SV and define a one-port that references the file to represent the discone antenna. Run a frequency sweep, then use the report editor in Serenade SV to graph the antenna impedance on a Smith Chart by asking for a polar plot of S_{11} and specify Z or Y coordinates, or both.

The discone model's impedance is presented in Figures 10 and 11. Both figures assume a 75 Ω reference impedance. Figure 10 shows the complex impedance curve on the Smith Chart. For antennas, which are passive loads, the curve bends clockwise as frequency increases. Figure 11 shows the resulting SWR, whose agreement with

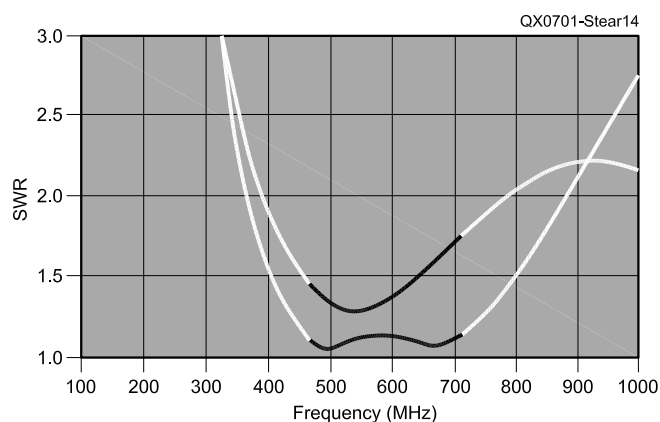


Figure 13 — The match performance of an open stub is shown on a 75 Ω Smith Chart.

Figure 9B confirms that the EZNEC data conversion was done correctly. The data is plotted for the one-decade band from 100 MHz to 1,000 MHz. The 0.6-octave UHF TV band, from 470 MHz to 710 MHz, is highlighted with a darker line. This is the region where we want to match the impedance.

The secret to understanding the behavior of this medium bandwidth discone is to note that discone impedance curves aren't uniform concentric spirals on a Smith Chart, like a dipole would be. Instead, the impedance curves have a small loop in the middle of every large loop. By varying the cone angle and disk radius, a small loop can be moved to the center of the Smith Chart. Then, by merely scaling the dimensions, nearly an octave of bandwidth can be slid into the small loop. This yields a moderately broadband low-SWR antenna, such as our example discone.

These steps can be done in reverse order: first put the UHF TV band in a small loop and then move the loop to the center of the Smith Chart by inserting an impedance matching network at the discone's feed point. With more work, however, the steps can be done in the original order, and the impedance matching network eliminated.

The simplest impedance matching network for the discone model is the 75 Ω open stub shown Figure 12. The stub was designed to match the antenna to 75 Ω and is made of 75- Ω transmission line. The stub is inserted in a 75- Ω feed line at the proper distance from the feed point. The stub's electrical length and position from the feed point (20.5° and 12.6° at 600 MHz) translate to physical lengths of 29 mm and 17 mm times the velocity factor of the transmission line. The network can be constructed by using a 75- Ω coaxial T connector. Because a physical stub terminates in a fringing capacitance rather than an ideal

infinite-impedance open circuit, a real stub must be made shorter to achieve the predicted performance. Rather than calculate the fringing capacitance, it's easy to trim the stub by measurement during construction.

The impedance matching performance of the stub matching network is shown in Figures 13 and 14. Figure 14 shows before and after SWR curves. The matching network reduces the maximum SWR in the UHF TV band from 1.28 to 1.12.

Although most amateurs think of low SWR as important for transmitting, it is also important for receiving digital modulations such as DTV signals. The game here is not about power transmission. Rather, it is about avoiding waveform distortion caused by frequency selectivity of the communications channel. Wideband digital signals hate reflections, regardless of source. Reflections from multipath propagation and transmission line discontinuities are equally bad. The question of where reflected power goes is, ultimately, unimportant because communication is about getting information through, not power. Power transmission is merely a means to a greater end, not the end in itself. Reflections should be avoided.

Discones and bicones are better antennas for receiving HDTV signals than bow-tie or flat triangle antennas although the latter are better than log periodics and Yagis when phase distortion is considered. A bicone is easier to design than a discone because you build two identical cones. The question of disk size disappears. That's one fewer variables to get right. Other things to consider are pattern and polarization. Antennas should be mounted with the correct polarization — vertical for VHF/UHF communication signals and horizontal for receiving FM and television broadcast signals. When mounted horizontally, the azimuthal gain pattern is like that of a horizontal dipole — a figure eight for low frequencies and increasingly multi-lobed as frequency increases. At high frequencies, a discone's main lobe lies in the half-space on the cone side of the disk. As frequency increases from low to high, the main lobe shifts from the plane of the disk toward the direction of the cone, and minor lobes emerge on both sides of the disk.

Acknowledgments:

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Parts of this article appeared in the newsletter of the Foothills Amateur Radio Society, an ARRL affiliated club. Those

portions are included here with permission.

Notes

¹The Institute of Radio Engineers (1912-1963) merged with the older American Institute of Electrical Engineers (1884-1963) to form the Institute of Electrical and Electronics Engineers (IEEE) in 1963. The IRE was instrumental in the creation of the Federal Radio Commission in 1927, which became the FCC in 1934.

²Mathematically skilled readers will find the papers by Hahn and Fikioris and by Samaddar and Mokole contain rigorous extensions of Schelkunoff's original analysis.

Steve Stearns, K6OIK, started in Amateur Radio while in high school at the height of the Heathkit era. He holds an FCC Amateur Extra license and a commercial General Radiotelephone Operator license with Radar endorsement. He previously held Novice, Technician, and 1st Class Radiotelephone licenses. He studied electrical engineering at California State University Fullerton, the University of Southern California, and Stanford University, specializing in electromagnetics, communication engineering and signal processing. Steve works at Northrop Grumman's Electromagnetic Systems Laboratory in San Jose, California, where he developed smart antenna and digital demodulation technology for eliminating interference and is currently developing ways to design and fabricate metamaterials to control electromagnetic phenomena. He has over 50 professional publications and eight US patents and numerous foreign patents. Steve is an ARRL Life member, has served as an assistant director of ARRL Pacific Division, and is currently the vice-president of Foothills Amateur Radio Society serving Silicon Valley. Steve has received numerous awards for professional and community volunteer activities. He can be reached at k6oik@arrl.net or stearns@ieee.org.

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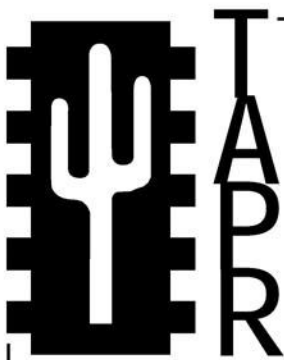
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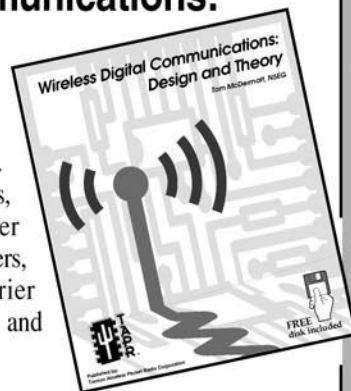
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each element needs to be about 1% or 2% longer than a simple dipole at the same frequency. As a rule of thumb, use $477/f$ (in feet) instead of the usual $468/f$ when calculating dipole length, and $239/f$ instead of $234/f$ for a $\lambda/4$ vertical.

A 30/17/12-Meter Dipole

To show how a C-R antenna is designed, let's build a dipole to cover all three WARC bands. We'll use #12 wire, which has a diameter of 0.08 inches, and the main dipole will be cut for the 10.1 MHz band. From the equation above, the spacing between the main dipole and the 18-MHz resonator should be 2.4 inches for 72 Ω , or 1.875 inches for 50 Ω . At 24.9 MHz, the spacing to the resonator for that band should be 2.0 inches for 72 Ω , or 1.62 inches for 50 Ω . Of course, this antenna will be installed over real ground, not in free space, so these spacing distances may not be exact. Plugging these numbers into your favorite antenna-modeling program will let you optimize the dimensions for installation at the height you choose.

For those of you who like to work with real antennas, not computer-generated ones, the predicted spacing is accurate enough to build an antenna with minimum trial-and-error. You should use a nice round number just larger than

the calculated spacing for 50 Ω . For this antenna, K9AY decided that the right spacing for the desired height would be 2 inches for the 18 MHz resonator and 1.8 inches for the 24.9 MHz resonator. For simplicity of construction, he just used 2 inches for both, figuring that the worst he would get is a 1.2:1 SWR if the numbers were a little bit off. Like all dipoles, the impedance varies with height above ground, but the 2-inch spacing results in an excellent match on the two additional bands, at heights of more than 25 feet.

The final dimensions of the dipole for 10.1, 18.068 and 24.89 MHz are shown in **Fig 47**. These are the final pruned lengths for a straight dipole installed at a height of about 40 feet. If you put up the antenna as an inverted V, you will need each wire to be a bit longer. Pruning this type of antenna is just like a dipole—if it's resonant too low in frequency, it's too long and the appropriate wire needs to be shortened. So, you can cut the wires just a little long to start with and easily prune them to resonance.

A final note: if you want to duplicate this antenna design, remember that the 2-inch spacing is just for #12 wire! The required spacing for a C-R antenna is related to the conductor diameter. This same antenna built with #14 wire needs under 1½-inch spacing, while a 1-inch aluminum-tubing version requires about 7-inch spacing.

Summary

The coupled-resonator principle is one more weapon in the antenna designer's arsenal. It's not the perfect method for all multiband antennas, but what the C-R principle offers is an alternative to traps and tuners, in exchange for using more wire or aluminum. Although a C-R antenna requires more complicated construction, its main attraction is in making a multiband antenna that can be built with no compromise in matching or efficiency.

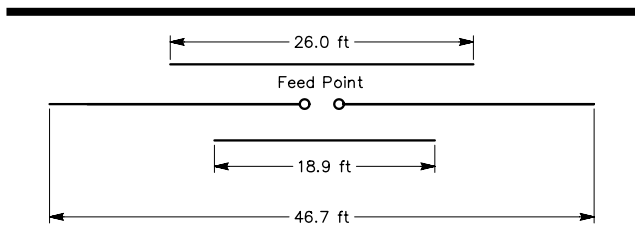


Fig 47—Dimensions of a C-R dipole for the 30, 17 and 12-meter bands.

HF Discone Antennas

The material in this section is adapted from an article by Daniel A. Krupp, W8NWF, in *The ARRL Antenna Compendium, Vol 5*. The name *discone* is a contraction of the words disc and cone. Although people often describe a discone by its design-center frequency (for example, a “20-meter discone”), it works very well over a wide frequency range, as much as several octaves. **Fig 48** shows a typical discone, constructed of sheet metal for UHF use. On lower frequencies, the sheet metal may be replaced with closely spaced wires and/or aluminum tubing.

The dimensions of a discone are determined by the lowest frequency of use. The antenna produces a vertically polarized signal at a low-elevation angle and it presents a good match for 50- Ω coax over its operating range. One

advantage of the discone is that its maximum current area is near the top of the antenna, where it can radiate away from ground clutter. The cone-like skirt of the discone radiates the signal—radiation from the disc on top is minimal. This is because the currents flowing in the skirt wires essentially all go in the same direction, while the currents in the disc elements oppose each other and cancel out. The discone's omnidirectional characteristics make it ideal for roundtable QSOs or for a Net Control station.

Electrical operation of this antenna is very stable, with no changes due to rain or accumulated ice. It is a self-contained antenna—unlike a traditional ground-mounted vertical radiator, the discone does not rely on a ground-radial system for efficient operation. However, just like any other vertical

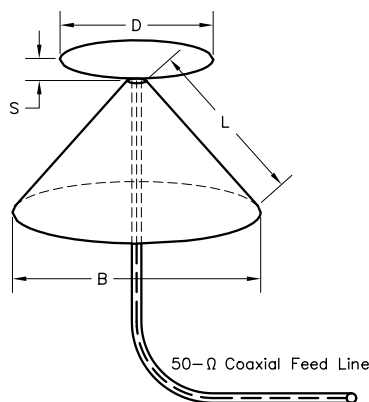


Fig 48—Diagram of VHF/UHF discone, using a sheet-metal disc and cone. It is fed directly with 50-Ω coax line. The dimensions L and D, together with the spacing S between the disc and cone, determine the frequency characteristics of the antenna. $L = 246 / f_{\text{MHz}}$ for the lowest frequency to be used. Diameter D should be from 0.67 to 0.70 of dimension L. The diameter at the bottom of the cone B is equal to L. The space S between disc and cone can be 2 to 12 inches, with the wider spacing appropriate for larger antennas.

antenna, the quality of the ground in the Fresnel area will affect the discone's far-field pattern.

Both the disc and cone are inherently balanced for wind loading, so torque caused by the wind is minimal. The entire cone and metal mast or tower can be connected directly to ground for lightning protection.

Unlike a trap vertical or a triband beam, discone antennas are not adjusted to resonate at a particular frequency in a ham band or a group of ham bands. Instead, a discone functions as a sort of high-pass filter, efficiently radiating RF all the way from the low-frequency design cutoff to the high-frequency limits imposed by the physical design.

While VHF discones have been available out-of-the-box for many years, HF discones are rare indeed. Some articles have dealt with HF discones, where the number of disc elements and cone wires was minimized to cut costs or to simplify construction. While the minimalist approach is fine if the sought-after results really are obtained, W8NWF believes in building his discones without compromise.

History of the Discone

The July 1949 and July 1950 issues of *CQ* magazine both contained excellent articles on discones. The first article, by Joseph M. Boyer, W6UYH, said that the discone was developed and used by the military during World War II. (See Bibliography.) The exact configuration of the top disc and cone was the brainchild of Armig G. Kandonian. Boyer described three VHF models, plus information on how to build them, radiation patterns, and most importantly, a detailed description of how they work. He referred to the

discone as a type of "coaxial taper transformer."

The July 1950 article was by Mack Seybold, W2RYI. He described an 11-MHz version he built on his garage roof. The mast actually fit through the roof to allow lowering the antenna for service. Seybold stated that his 11-MHz discone would load up on 2 meters but that performance was down 10 dB compared to his 100-MHz Birdcage discone. He commented that this was caused by the relatively large spacing between the disc and cone. Actually, the performance degradation he found was caused by the wave angle lifting upward at high frequencies. The cone wires were electrically long, causing them to act like long wire antennas. See Fig 49.

W8NWF's First Discone: the A-Frame Discone

The first discone was one designed to cover 20 through 10 meters without requiring an antenna tuner. The cone assembly uses 18-foot long wires, with a 60° included apex angle and a 12-foot diameter disc assembly. See Fig 50 and Fig 51. The whole thing was assembled on the ground, with the feed coax and all guys attached. Then with the aid of some friends, it was pulled up into position.

The author used a 40-foot tall wooden "A-frame" mast, made of three 22-foot-long 2 × 4s. He primed the mast with sealer and then gave it two coats of red barn paint to make it look nice and last a long time. The disc hub was a 12-inch length of 3-inch schedule-40 PVC plumbing pipe. The PVC is very tough, slightly ductile, and easy to drill and cut. PVC is well suited for RF power at the feed point of the antenna.

Three 12-foot by 0.375-inch OD pieces of 6061 aluminum, with 0.058-inch wall thickness, were used for the 12-foot diameter top disc. These were cut in half to make the center portions of the six telescoping spreaders. Four twelve foot by 0.250-inch OD (0.035-inch wall thickness) tubes were cut into 12 pieces, each 40 inches long. This gave extension tips for each end of the six spreaders.

See Fig 52 for details on the disc hub assembly. W8NWF started by drilling six holes straight through the PVC for the six spreaders, accurately and squarely, starting

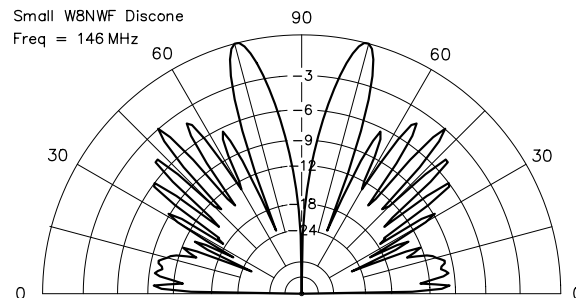


Fig49—Computed elevation plot over average ground for W8NWF's small discone at 146 MHz, ten times its design frequency range. The cone wires are acting as long-wire antennas, distorting severely the low-elevation angle response, even though the feed-point impedance is close to 50 Ω.



Fig 50—Photo of W8NWF's original A-frame mounted HF disccone.

about two inches down from the top and spaced radially every 30°. Each hole is 0.375 inches below the plane of the previous one. Take great care in drilling—a poor job now will look bad from the ground up for a long time! It's a good idea to make up a paper template beforehand. Tape this to the PVC hub and then drill the holes, which should make for a close fit with the elements. If you goof, start over with a new piece of PVC—it's cheap.

Each six-foot spreader tube was secured exactly in the center to clear a 6-32 threaded brass rod that secured the elements mechanically and electrically. A two-foot long by ¼-inch OD wooden dowel was inserted into the middle of each six-foot length of tubing. The dowel added strength and also prevented crushing the element when the nuts on the threaded rod were tightened.

Insert the 40-inch long extensions four inches into each end of the six-foot spreaders. Mark and drill holes to pin the telescoping tips, plus holes big enough to clear #18 soft-drawn copper wire. This was for the inner circumferential wire for the disc. Drill a single hole for #18 wire about ¼ inch from each extension element tip, through which passes the outer circumferential wire. Finally, insert all 6-foot elements into the PVC hub and line up the holes in the center so the brass rod could be inserted through the middle to secure the elements.

The next step is to “chisel to fit” the top of my wooden mast to allow the PVC to slide down on it about six or seven inches. For convenience, place the whole mast assembly in a horizontal position on top of two clothesline poles and one stepladder.

Place the disc head assembly over the top of the mast, but don't secure it yet. This allows for rotation while adding the disc spreader extensions. A tip for safety: tie white pieces of cloth to the ends of elements near eye level. Just remember to remove them before raising the antenna.

For a long-lasting installation, use an anti-corrosion compound, such as Penetrox, when assembling the aluminum antenna elements. As the extensions are added, secure them in the innermost of the two holes with a short piece of #18 wire. Then run a wire through the remaining holes looping each element as you go. This gives added support laterally to the elements. Next add a #18 wire to the tips of the extensions in the same fashion. This provides even more

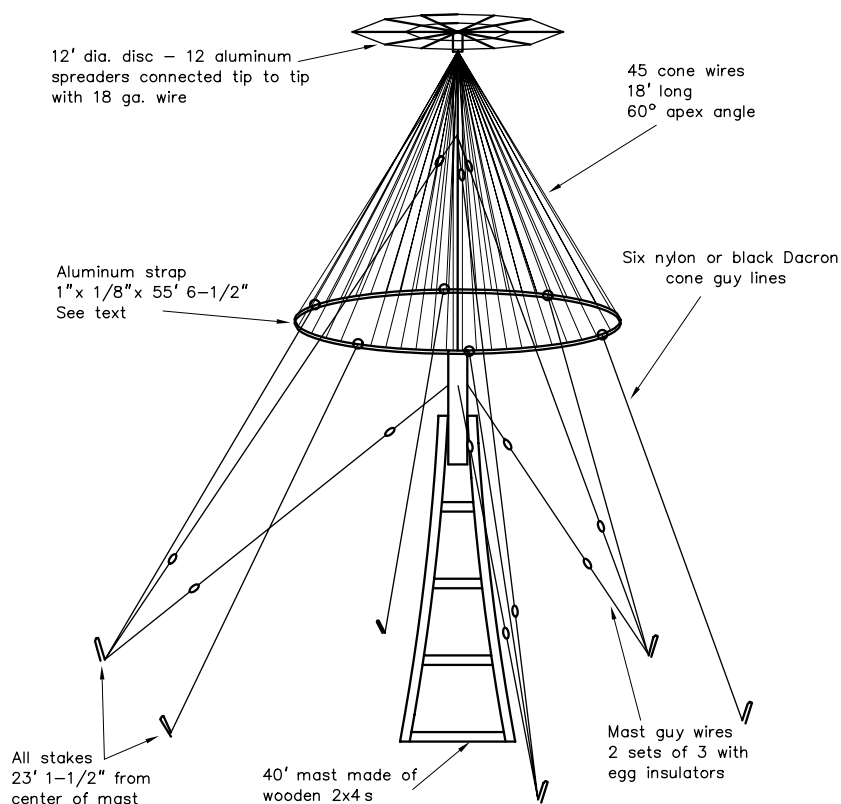


Fig 51—Detailed drawing of the A-frame disccone for 14 to 30 MHz. The disc assembly at the top of the A-frame is 12 feet in diameter. There are 45 cone wires, each 18 feet long, making a 60° included angle of the cone. This antenna works very well over the design frequency range.

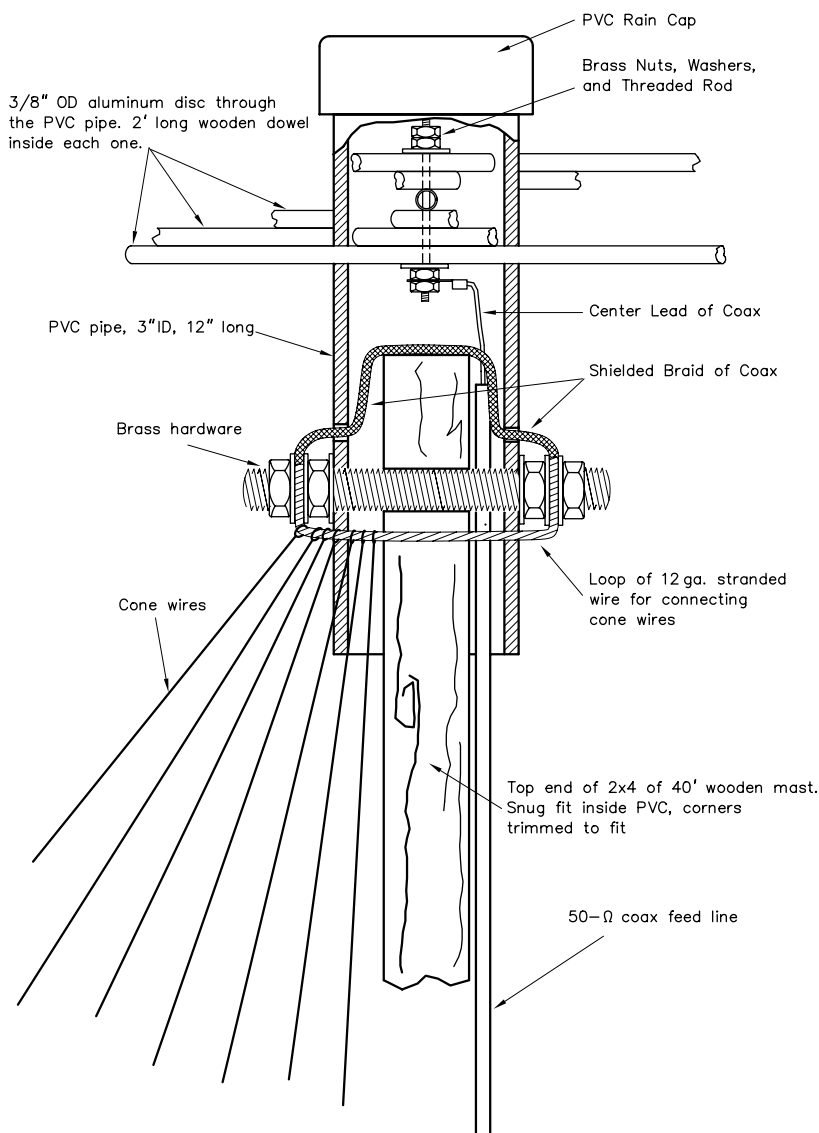


Fig 52—Details of the top hub for the A-frame discone. The three-inch PVC pipe was drilled to hold the six spreaders making up the top disc. Connections for the shield of the feed coax were made to the disc. The coax center conductor was connected to the cone-wire assembly by means of a loop of #12 stranded wire encircling the outside of the PVC hub.

physical stability as well as making electrical connections.

Next, pin the PVC disk hub to the wooden mast with a $\frac{3}{8}$ -inch threaded rod. This is also the point where the cone wires are attached, using a loop of #12 stranded copper wire around the PVC. Solder each cone wire to this loop, together with the coax shield braid. Make sure the loop of #12 wire is large enough to make soldering possible without burning the PVC with the soldering iron.

Connect the coax center conductor to the disc assembly by securing it with the same 6-32 threaded rod that ties all the disc elements together. Make sure to use coax-seal compound to keep moisture out of the coax. The coax is then fed down the mast and secured in a few places to provide strain relief and to keep it out of the way of the cone wires.

Use two sets of three guy wires. Break these up with egg insulators, just to be sure there won't be any interaction with the antenna. Use 45 wires of #18 soft-drawn copper wire

for the cone, 18 feet long each. Cut them a little long so they can be soldered to the connecting loop.

A difficult task is now at hand—keeping all the cone wires from getting tangled! Solder each of the 45 cone wires to the loop of #12 wire, spacing each wire about $\frac{1}{4}$ inch from the last one for an even distribution all the way around.

The cone base is 18 feet in diameter to provide a 60° included angle. At the base of the cone, use five 12-foot long aluminum straps, 1 inch wide by $\frac{1}{8}$ inch thick, overlapping $8\frac{1}{4}$ inches and fastened together with aluminum rivets. Drill holes along the strap every 15 inches to secure the cone wires.

Make sure to handle the aluminum strap carefully while fastening the cone wire ends; too sharp of a bend could possibly break it. Fasten six small-diameter nylon lines to the cone-base aluminum strap to stabilize the cone. These cone-guys share the same guy stakes as the mast guy lines.

After cutting the nylon lines, heat the frayed ends of each with a small flame to prevent unraveling. Apply several coats of clear protective spray to the disk head assembly, after checking that all hardware is tight. A rain cap at the top of the PVC disc hub completes construction.

Putting It All Up

You are going to need a lot of help now to raise this antenna. Have the whole process fully thought out before trying to raise it. You should have the spot selected for the base of the mast and some pipes driven into the ground to prevent the mast from slipping sideways as it is being pulled up. The three guy stakes should be in place, 23 feet, 1½ inches from mast center. Of course, the guys should have been cut to the correct length, with some extra. Be sure the coax transmission line will come off the mast where it should. A long length of rope to an upper and lower guy line is used to pull up the whole works.

The author used an old trick of standing an extension ladder vertically near the antenna base with the pull lines looped over the top rung to get a good lift angle. The weight added to the mast from the antenna disc assembly and cone wires is about 26 pounds, most of it from the cone assembly. Use two strong people to pull up the antenna slowly so that the other helpers on the guy wires and cone guy lines have time to move about as required. As the antenna rises to the vertical position, if there are no snafus, the guy lines can be secured. Then tie the six cone lines to stakes.

A Really Big Discone

When an opportunity arose to buy a 64-foot self-supporting TV tower, the author jumped at the chance to implement a full 7 to 30-MHz discone. His new tower had eight sections, each eight feet long. Counting the overlap between sections, the cone wires would come off the tower at about the 61.5-foot mark.

W8NWF took some liberties with the design of this larger discone compared to the first one, which he had done strictly “by the book.” The first change was to make the cone wires 70 feet long, even though the formula said they should be 38 feet long. Further, the cone wires would not be connected together at the bottom. With the longer cone wires, he felt that 75 and 80-meter operation might be a possibility.

Fig 53—The large W8NWF discone, designed for operation from 7 to 14 MHz, but useable with a tuning network in the shack for 3.8 MHz.

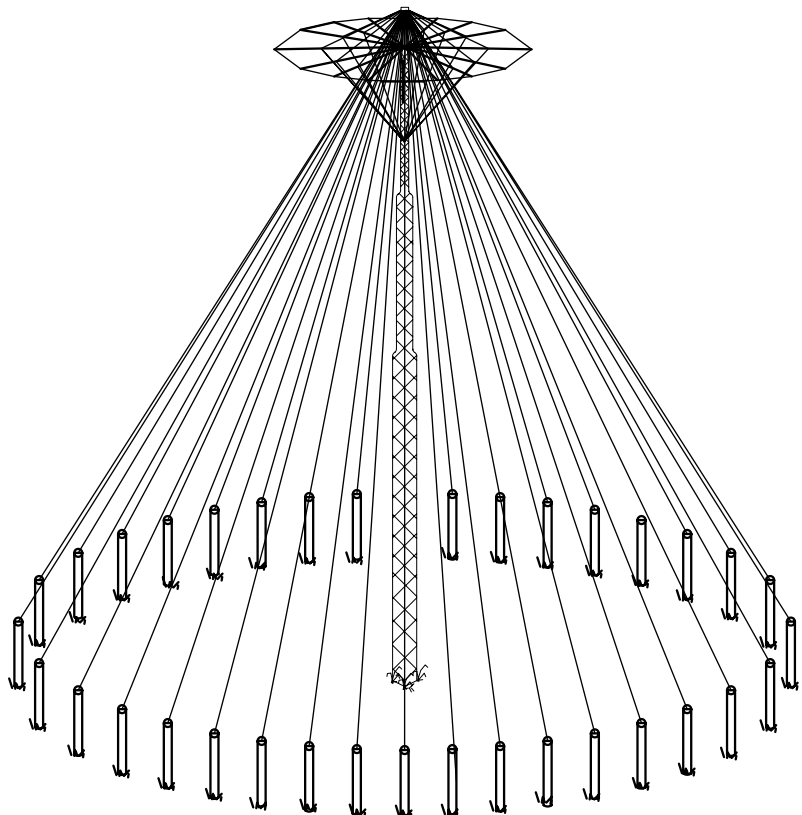
The second major change was to widen the apex angle out from 60° to about 78°. Modeling said this should produce a flatter SWR over the frequency spectrum and would also give a better guy system for the tower.

The topside disc assembly would be 27 feet in diameter and have 16 radial spreaders, using telescoping aluminum tubing tapering from ⅝ to ½ to ⅜ inches OD. All spreaders were made from 0.058-inch wall thickness 6063-T832 aluminum tubing, available from Texas Towers. A section of 10-inch PVC plumbing pipe would be used as the hub for construction of the disc assembly.

Construction Details for the Large Discone.

While installing the tower, the author had left the top section on the ground. This allowed him to fit the disc head assembly precisely to it. **Fig 53** shows the overall plan for the large discone. The 10-inch diameter PVC hub was designed to slip over the tower top section, but was a little too large. So a set of shims was installed on the three legs at the top of the tower for a just-right fit. Drilling the PVC pipe for the eight ⅝-inch OD elements was started about an inch down from the top. W8NWF purposely staggered the drilled holes in the same fashion as the hub for the smaller antenna. See **Fig 54**.

Again, three-foot sections of ½-inch wooden dowel were used to strengthen the ⅝-inch center portion of each spreader. Instead of using a loop of #12 wire for connecting the cone wires, as had been done on the smaller discone, he drilled 36 holes in the PVC hub. These holes are small enough so



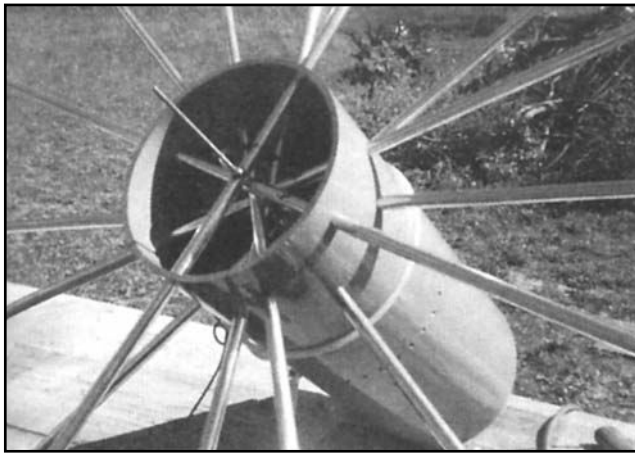


Fig 54—Photo showing details of the hub assembly for the large discone, including the threaded brass rod that connects the radial spreaders together. The 10-inch PVC pipe is drilled to accommodate the radial spreaders. Each spreader is reinforced with a three-foot long wooden dowel inside for crush resistance. Note the row of holes drilled below the lowest spreader. Each of the 36 cone wire passes through one of these holes.

that the PVC hub would not be weakened appreciably. He drilled the circles of holes for the cone wires about 6 inches below the disc spreaders.

He prepared a three-foot long piece of RG-213 coax, permanently fastened on one end to the antenna, with a female type-N connector at the other end. Type-N fittings were used because of their superior waterproofing abilities. The coax center lead was connected with a terminal lug under a nut on the brass threaded rod securing the disc spreaders. The coax shield braid was folded back over a six-inch long copper pipe and clamped to it with a stainless-steel hose clamp. See **Fig 55** for details.

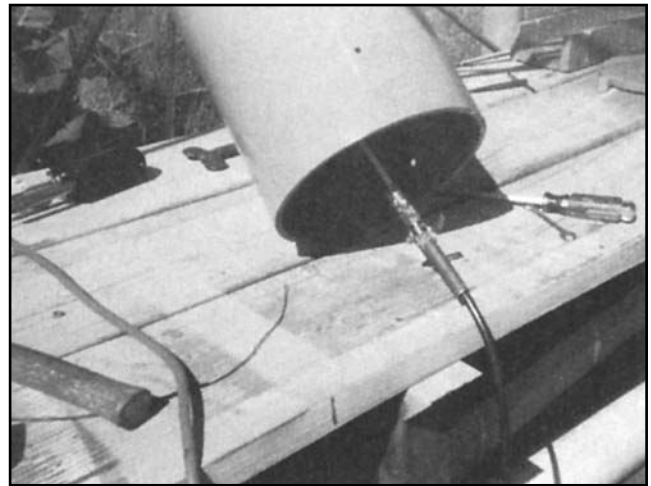


Fig 55—Details of the copper pipe slipped over the feed coax. The coax shield has been folded back over the copper pipe and secured with two stainless-steel hose clamps. The cone wires are also laid against the copper pipe and secured with additional hose clamps.

The plan was that after the top disc assembly had been hoisted up and attached at the top of the tower, individual cone wires would be fed, one at a time, through the small holes drilled in the PVC. They were to be laid against the copper pipe and secured with stainless-steel hose clamps.

The $\frac{1}{2}$ and $\frac{3}{8}$ -inch OD spreader extension tips were secured in place with two aluminum pop-rivets at each joint. Again, the author used anti-oxidant compound on all spreader junctions. He drilled a hole horizontally near the tip of each $\frac{3}{8}$ -inch tip all around the perimeter to allow a #8 aluminum wire to circle the entire disc. A small stainless-steel sheet-metal screw was threaded into the end of each element to secure the wire.

In parallel with the aluminum wire, a length of small-diameter black Dacron line was run, securing it in a couple of places between each set of spreaders with UV-resistant plastic tie-wraps. The reason for doing this was to hold the aluminum wire in position and to prevent it from dangling, in case it should break some years in the future. Two coats of clear protective spray were applied for protection.

A truss system helps prevent the disc from sagging due to its own weight. See **Fig 56** for details. This shows the completed disk assembly mounted on the

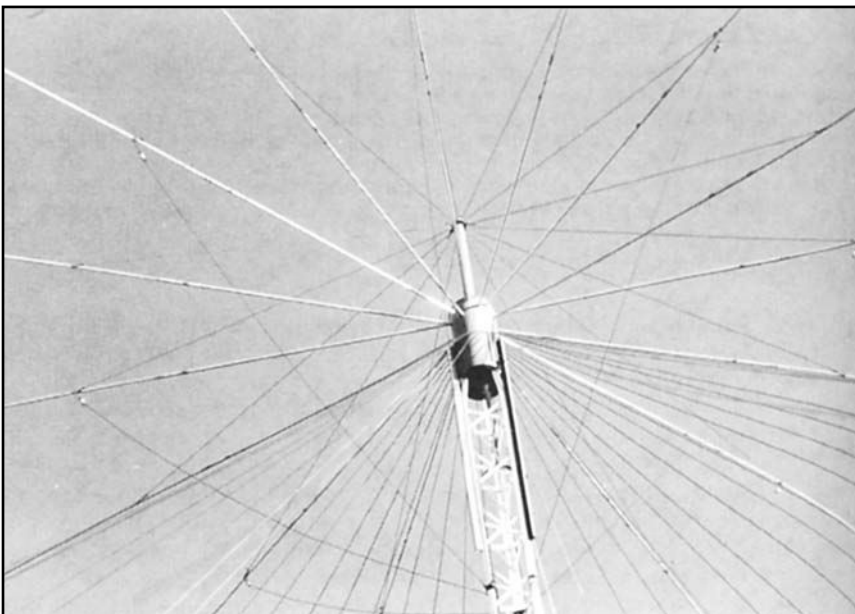


Fig 56—Photo of the spreader hub assembly, showing the truss ropes above and below the radial spreaders. This is a very rugged assembly!

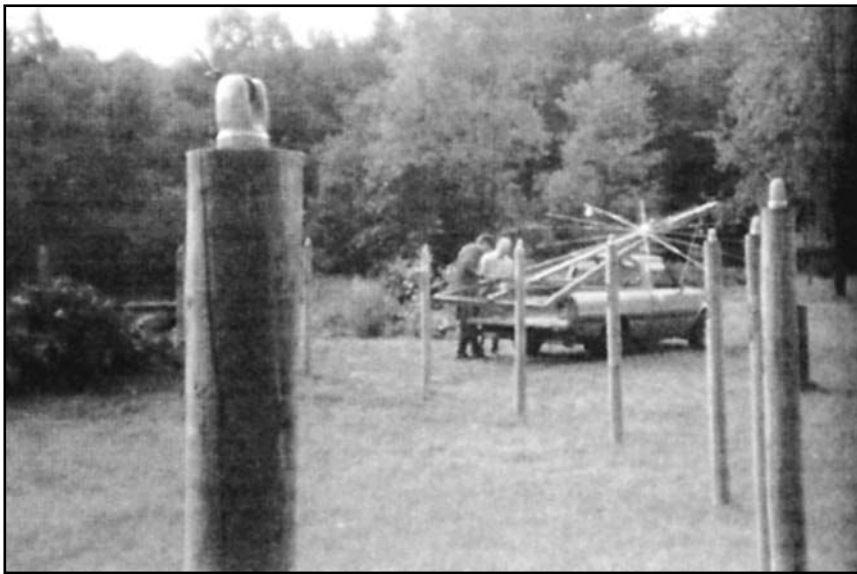


Fig 57—Photo showing some of the fence posts used to hold individual cone wires to keep them off the ground and out of harm's way. The truck in the background is carting away the A-frame discone for installation at KA8UNO's QTH.

top of the tower. A 3-foot length of 2-inch PVC pipe was used for a truss mast above the disc assembly, notching the bottom of the pipe so that it would form a saddle over the top couple of spreaders. This gave a good foothold. He cut a circle of thin sheet aluminum to fit over the 10-inch PVC to serve as a rain cap. The cap has a hole in the center for the two-inch PVC truss mast to pass through, thereby holding it down tight. The author sprayed a few light coats of paint over the PVC for protection from ultraviolet radiation from the sun.

Sixteen small-diameter black Dacron ropes were connected at the top of the truss support mast, with the other ends fastened to the disc spreaders, halfway out. Another rain cap was added to the top of the two-inch PVC truss mast. Eight lengths of the same small diameter Dacron rope were added halfway out the length of every other spreader. These ropes are meant to be tied back to the tower, to prevent updrafts from blowing the disc assembly upwards. Small egg insulators were used near the spot where the eight bottom trusses were tied to the disc spreaders, just to be sure there would be no RF leakage in rainy weather.

Hoisting the completed disc assembly to the top of the tower can be done easily, with the assistance of at least two others. The trickiest part is to get the disc assembly from its position sitting flat on the ground to the vertical position needed for hoisting it up the tower without damaging it. The disc assembly weighs about 35 pounds. Someone at the top of the tower will receive the disc as it is hoisted up by gin pole, and can mount it on the tower top.

You should prepare three 6-foot long metal braces going over the outside of the PVC to fasten to the tower legs. They really beef things up.

In plastic irrigation pipe buried between the house and tower base, the author ran 100 feet of 9086 low-loss coax to the shack. For cone wires, he was able to obtain some #18 copperclad steel wire, with heavy black insulation that looked a lot like neoprene. The cone system takes a lot of

wire: 36×70 feet = 2520 feet, plus some extra at each end for termination. You'd be well advised to look around at hamfests to save money.

As each cone wire was connected at the top of the tower, a helper should place the other end at its proper spot below. The lower end of each cone wire is secured to an insulator screwed into a fencepost. See **Fig 57**. There are 36 treated-pine fenceposts, each standing about $5\frac{1}{2}$ feet tall, 45 feet from the tower base to hold the lower end of the cone wires. This makes mowing the grass easier and the cone wires are less likely to be tripped over too.

On the final trip down the tower, the eight Dacron downward-truss lines were tied back to the tower about 6 feet below the disc assembly. The author's tower has three ground rods driven near the base, connected with heavy copper wire to the three tower legs.

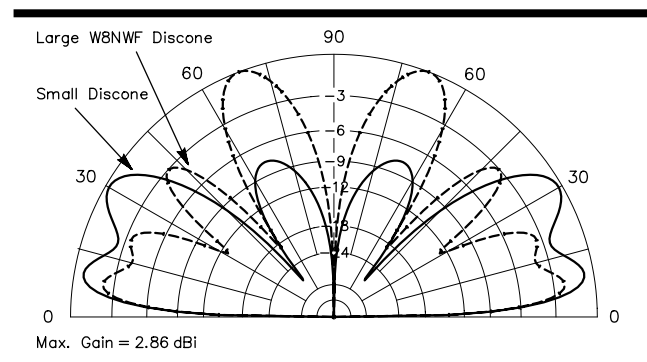


Fig 58—Computed patterns showing elevation response of small discone at 28.5 MHz compared to that of the larger discone at 28.5 MHz. The cone wires are clearly too long for efficient operation on 10 meters, producing unwanted high-angle lobes that rob power from the desirable low-elevation angles.

Performance Tests

On the air tests proved to be very satisfying. Loading up on 40 meters was easy—the SWR was 1:1 across the entire band. W8NWF can work all directions very well and receives excellent signal reports from DX stations. When he switches to his long (333 foot) center-fed dipole for comparison, he finds the dipole is much noisier and that received signals are weaker. During the daytime, nearby stations (less than about 300 to 500 miles) can be louder with the dipole, but the discone can work them just fine also.

The author happily reports that this antenna even works well on 75 meters. As you might expect, it doesn't present a 1:1 match. However, the SWR is between 3.5:1 and 5.5:1 across the band. W8NWF uses an antenna tuner to operate the discone on 75. It seems to get out as well on 75 as it does on 40 meters.

The SWR on 30 meters is about 1.1:1. On 20 meters the SWR runs from 1.05:1 at 14.0 MHz to 1.4:1 at 14.3 MHz. The SWR on the 17, 15, 12 and 10-meter bands varies, going up to a high of 3.5:1 on 12 meters.

Radiation Patterns for the Discones

From modeling using *NEC/Wires* by K6STI, W8NWF verified that the low-angle performance for the bigger antenna is worse than that for the smaller discone on the upper frequencies. See **Fig 58** for an elevation-pattern comparison on 10 meters for both antennas, with average ground constants. The azimuth patterns are simply circles. Radiation patterns produced by antenna modeling programs are very helpful to determine what to expect from an antenna.

The smaller discone, which was built by the book, displays good, low-angle lobes on 20 through 10 meters. The frequency range of 14 through 28 MHz is an octave's worth of coverage. It met his expectations in every way by covering this frequency span with low SWR and a low angle of radiation.

The bigger discone, with a modified cone suitable for use on 75 meters, presents a little different story. The low-angle lobe on 40 meters works well, and 75-meter performance also is good, although an antenna tuner is necessary on this band. The 30-meter band has a good low-angle lobe

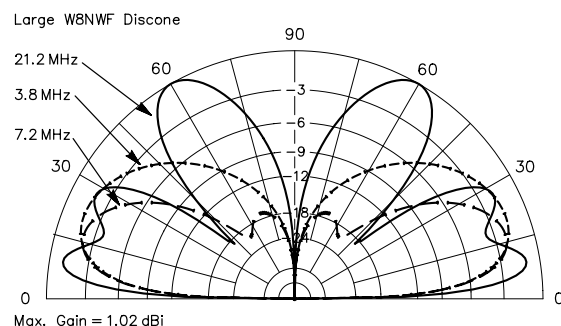


Fig 59—Computed elevation-response patterns for the larger W8NWF discone for 3.8, 7.2 and 21.2 MHz operation. Again, as in Fig 58, the pattern degrades at 21.2 MHz, although it is still reasonably efficient, if not optimal.

but secondary high-angle lobes are starting to hurt performance. Note that 30 meters is roughly three times the design frequency of the cone. On 20 and 17 meters there still are good low-angle lobes but more and more power is wasted in high-angle lobes.

The operation on 15, 12, and 10 meters continues to worsen for the larger discone. The message here is that although a discone may have a decent SWR as high as 10 times the design frequency, its radiation pattern is not necessarily good for low-angle communications. See **Fig 59** for a comparison of elevation patterns for 3.8, 7.2 and 21.2 MHz on the larger discone.

A discone antenna built according to formula will work predictably and without any adjustments. One can modify the antenna's cone length and apex angle without fear of rendering it useless. The broadband feature of the discone makes it attractive to use on the HF bands. The low angle of radiation makes DX a real possibility, and the discone is also much less noisy on receive than a dipole.

Probably the biggest drawback to an HF discone is its bulky size. There is no disguising this antenna! However, if you live in the countryside you should be able to put up a nice one.

Notes on HF Discone Antennas

L. B. Cebik, W4RNL

The discone antenna is a broadband basic antenna originally designed for VHF-UHF service. Indeed, it is a staple for upper-range scanning receivers. Developed during WWII by A. G. Kandoian, and brought to the attention of radio amateurs in the later 1940s, the following years saw conversions of the design to HF use. Amateurs have used it from 160 meters up through 10 meters, although the operating passband for any single implementation is limited to about a 2.5:1 frequency range.

Even though the antenna is quite basic in concept, its shape seems to elicit strange reactions from newer amateurs. The reactions run from simple quizzical looks to occasional bizarre explanations of its operation. In these notes we shall look at the antenna with a series of inquiries. We shall start by putting the antenna into its proper class. Then we shall turn to questions of modeling the antenna, sorting out what we can glean from models and what we cannot. Since operating bandwidth is the most pressing question in many minds, we shall next look at that matter, followed by questions of performance. The performance facets of HF versions of the antenna over ground are perhaps the most important, since that is the environment in which we must use the antenna, if we choose to build one. To set a proper framework for judgment by the prospective builder, we shall look at a few other antenna designs that may be relevant.

In order to focus our attention on the properties of the HF discone, we shall confine our attention to creating one to cover the upper HF set of amateur allocations from 14 to 30 MHz. In the main—with a few exceptions—we shall use AWG #12 wires for the structure. AWG #12 wire has a diameter of 0.0808", just larger than the European counterpart common wire that is 2-mm in diameter.

Classifying the Discone

The discone antenna label is a concatenation of "disc" and "cone." The original versions of the antenna consisted of a lower conical section (point upward) topped by a solid disc. Between the center of the disc and the point of the cone we create a small space with a wire to which we attach a feedline, one side to the disc and the other to the cone. The feedpoint impedance of early versions proved to be compatible with the impedance of common coaxial cables (50-75- Ω). By routing the cable down the center of the cone—along a supporting mast—we simplified feeding the antenna in most situations.

To understand what the antenna really is, we should follow the progression of antennas sketched in **Fig. 1**. On the left, we have a common center-fed dipole. Except for the widest amateur bands, simple dipoles have operating bandwidths that cover most of the amateur bands. However, for increased bandwidth, we may construct biconical dipoles, shown next to the linear version. A biconical dipole has some interesting properties due to its element shape. The conical half elements tend to yield a broad impedance band that extends well beyond the range of a linear element. In addition, the SWR track of the antenna tends to show two low points, one near each end of the usable passband. These properties of the biconical shape have been known since the earliest days of antenna engineering, but came into prominence with the emergence of special needs for broadband EMI investigations, especially in the VHF-UHF range. Nonetheless, the biconical dipole remains simply a dipole.

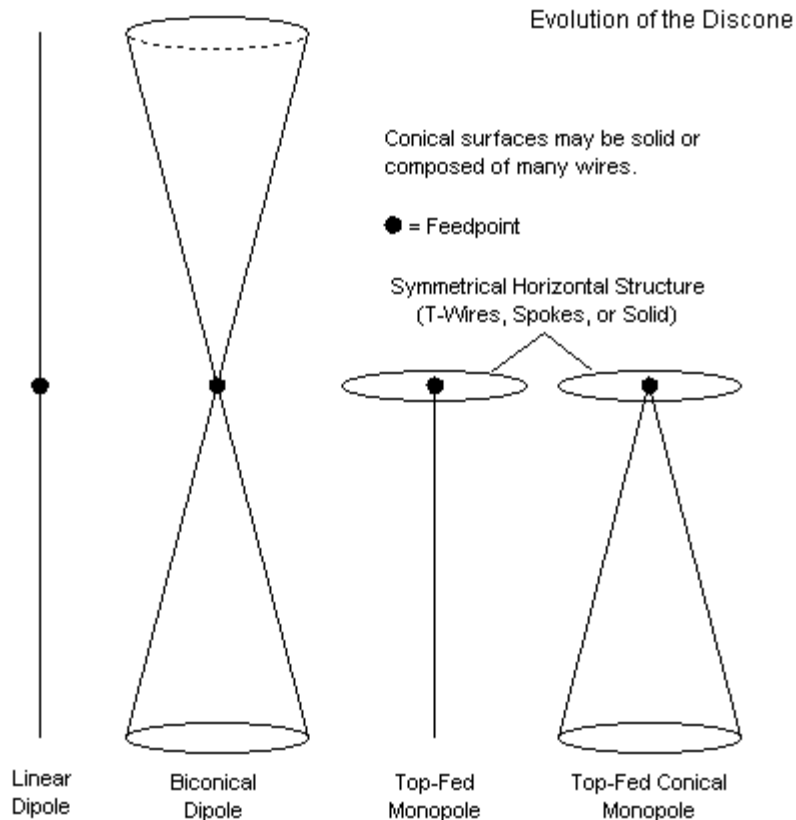


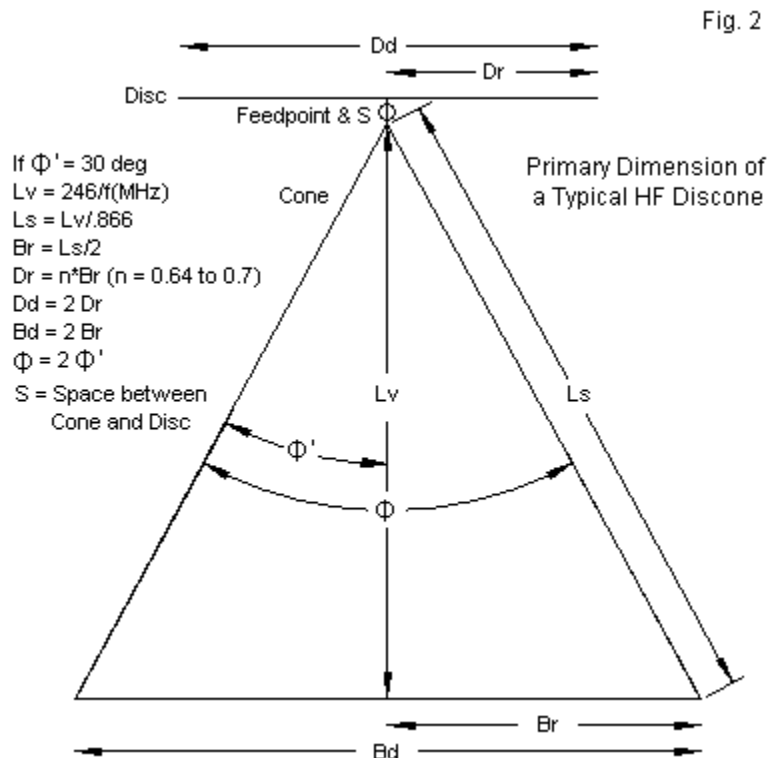
Fig. 1

We may remove one leg of a dipole to form a monopole under the condition that we replace the missing leg with a symmetrical or nearly symmetrical structure. The common elevated monopole with 4 radials is a primary example of the technique. The antenna is a monopole to the extent that effective radiation occurs only from the vertical leg of the structure. In principle, however, the antenna becomes an asymmetrical dipole in terms of the current on the various parts of the antenna. If we have a single vertical element and 4 radial legs, then the current next to the feedpoint at the junction on the vertical leg is also present on each of the radial legs at $\frac{1}{4}$ the value. If the radial legs are truly symmetrical, then the radiation from them is virtually self-canceling. The radial-leg structure can vary from a few linear radials to many such radials to a solid disc. As the number of radials increase, their necessary length to create feedpoint resonance with a given vertical leg decreases. Somewhere in the range of 60 radials, the diameter of the radial structure is the same as for a solid disc.

When elevated above ground, a vertical monopole with radials will operate equally well with the radial set at the top or at the bottom, so long as the feedpoint is at the junction of the vertical and the horizontal portions of the antenna. Top-fed T structures are sometimes used in both amateur and professional service. T-wires are merely a simplified version of the symmetrical radial or disc system.

Finally, to broaden the operating passband of the top-fed monopole, we may replace the linear vertical leg with a conical section, as shown at the right in **Fig. 1**. Essentially, a discone is a top-fed conical monopole, a brother to the standard linear monopole. Like the biconical dipole, the discone will show a broad SWR pattern with its lowest values near the low end and near the high end of the operating range.

Properly classifying the discone antenna removes some of the initial mystery from our understanding of its operating principles. However, it does not tell us how to build a successful HF discone. Most of the dimensional information on the discone derives ultimately from early VHF-UHF studies of the antenna. The most complete set of equations available to amateurs appear in a 1975 *QST* article by Jack Belrose, VE2CV. (See the short reference list at the end for some useful discone articles.) Perhaps the most significant dimension of the discone is the angle Φ between the outer walls of the cone. However, most implementations of the discone use a convenient value for this angle: 60° . Hence, Φ' ($1/2$ of Φ) is an equally convenient 30° , a value that simplifies calculations, both for construction and for modeling the antenna. If we focus on this value for Φ' , we obtain the set of dimensional relationships shown in **Fig. 2** for an HF discone measured in feet. You may adjust the constant in the equation for L_v to obtain the measurements in other units.



Because we are not working with a linear dipole or monopole, we are not looking for a set of equations that yields a self-resonant antenna at one frequency. Belrose likened the antenna to a high-pass filter with a low-frequency cut off. The analogy is apt and defines the reason for using the vertical length, L_v , as the dimension that should be about an electrical quarter wavelength at the lowest operating frequency. As well, the original equations for the discone presumed a solid-surface conical section (and disc). The use of a wire framework to simulate the surface is imperfect and the lower limit of the passband decreases as we add more wires.

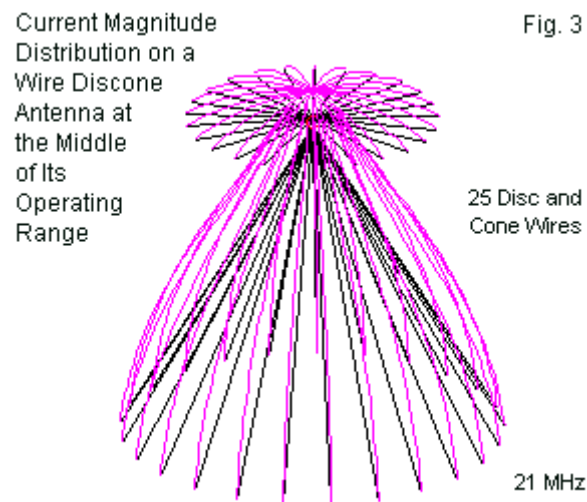
Note that the disc diameter is only about 0.64 to 0.7 the diameter of the open end of the cone. Because we may roughly calculate the disc size based on the largest diameter of the cone misleads newcomers into believing that there is an intrinsic relationship between the two values. However, the relationship is more circuitous. Suppose that we construct a simple monopole with 4 radials such that the current in each radial is $1/4$ the current in the vertical

element. The resonant feedpoint impedance of such a quasi-perfect monopole antenna will be in the 20-25- Ω range. To obtain a 50- Ω impedance without altering the angle of the radials with respect to the vertical leg, we must rearrange the element lengths. Either we may lengthen the radials and shorten the vertical, or we may lengthen the vertical and shorten the radials. In effect, we are creating an off-center-fed dipole structure with the lengths determined by the feedpoint impedance goal. The same reasoning applies to the discone. The disc radius is shorter than the value of L_v or of L_s (the sloping length of the cone) due to wishing for a certain feedpoint impedance. Because the disc interacts with the sides of the cone, the actual behavior of the discone differs from the simple monopole situation.

Modeling Issues

For a discone designed to operate from 14 to 30 MHz, we shall use the following dimensions in models. $L_v = 17.57'$. $L_s = 20.29'$. $Br = 10.15'$. Dr normally will be $6.8'$ (0.67 of Br). We shall use mainly 25 wires in the cone and in the disc, although we shall look at the effect of increasing the wire count to 45 wires in each part of the structure. Most of the models will not employ a perimeter wire for either the disc or the cone, although builders vary in their construction practices in this regard.

Fig. 3 shows the current distribution along the wires of a typical discone model at 21 MHz, about the middle of the operating range. Although the complexity of the structure may obscure some of the fine detail, we can see that the discone current magnitude distribution follows the basic pattern that we would find in a simple monopole with a minimum number of radials.



NEC models of discones are subject to some limitations. Many models of VHF-UHF discones tend to fail because the structures use relatively fat wires (as a fraction of a wavelength) coming together at angles that result in wire interpenetrations at the cone's point. At HF, the use of relatively thin wire obviates that problem. However, the spacing (S) between the cone's point and the center of the disc remains a problem. In practice, this distance may range from a very small measure to perhaps $2'$, depending on the frequency of operation.

The segment length in the primary models falls between $0.5'$ and $0.6'$ per segment. At this segment length, models may range from 1100 to 2000 segments, depending on the number of wires used in the cone and the disc. Shorter segments would tend to increase the segment

count per model to yield unwieldy model run times, especially in performance sweeps. The segment length in the main wires allows only 1 segment for the wire connecting the cone to the disk. NEC recommends that the segments on either side of the source segment be equal in length to each other and to the source segment. However, the complex structure does not yield the most ideal average gain test (AGT) score if we make the source wire (and hence the disc-to-cone separation) equal in length to the wire segments. Hence, I have simply adjusted the source wire length and the disc-to-cone separation to yield the best AGT score and therefore the most reliable model values as measured internally to the model. A value of about 0.37' turns out to be very close to optimal for the models. In fact, **Fig. 4** shows a simplified wire table for a disccone model. Only one wire appears for the disc and for the cone, but you may assume an additional 24 or 44 wires for each structure, depending on the model used.

No.	End 1				End 2				Diameter (in)	Segs
	X (ft)	Y (ft)	Z (ft)	Conn	X (ft)	Y (ft)	Z (ft)	Conn		
1	0	0	0	W2E1	10.15	0	-17.57		#12	33
2	0	0	0	W1E1	0	0	0.37	W3E1	#12	1
3	0	0	0.37	W2E2	6.8	0	0.37		#12	11

Because the source wire length and hence the separation of the disc and the cone result from modeling considerations, the physical distance between the two antenna sections may not correspond with the model. Therefore, the model will have some limitations relative to any physical implementation of a disccone. The primary limitation will involve the exact values of the reported impedances. Although the values will be reliable relative to the model, they may not be fully reliable relative to a physical implementation of the design. For the model shown, the main antenna segments are about 0.615' long, compared to the source segment's 0.37' length. For the range of models used, AGT values fall between 0.990 and 1.010. The range allows a comparison of impedance values among variations on a design, but the absolute values of the impedances may not be perfectly accurate. Since our general goal is to show trends in performance among variations, the possible lack of model-to-implementation correlation should create no significant difficulties.

The Operating Passband

Amateur radio operators define an operating passband for basic antennas in terms of the 2:1 SWR ratio. For the disccone, we may use a reference impedance of 50 Ω , on the presumption of wishing to operate the antenna with a direct connection between the antenna source point and a coaxial cable feedline. We shall look at a number of variations on the basic model, described earlier as a 25-wire AWG #12 version of the antenna. Sweeps will cover from 12 to 36 MHz in 1-MHz increments to show both the relatively sharp cut-off at the lower end of the operating passband and the shallower rise of impedance at the high end. For this basic model, with a disc diameter that is 0.67 the diameter of the open end of the cone, **Fig. 5** shows the 50- Ω and 75- Ω SWR curves. The 14-MHz 50- Ω SWR is slightly above the 2:1 usual amateur limit, suggesting that for this particular model, one might like to increase dimensions proportionately by a small amount.

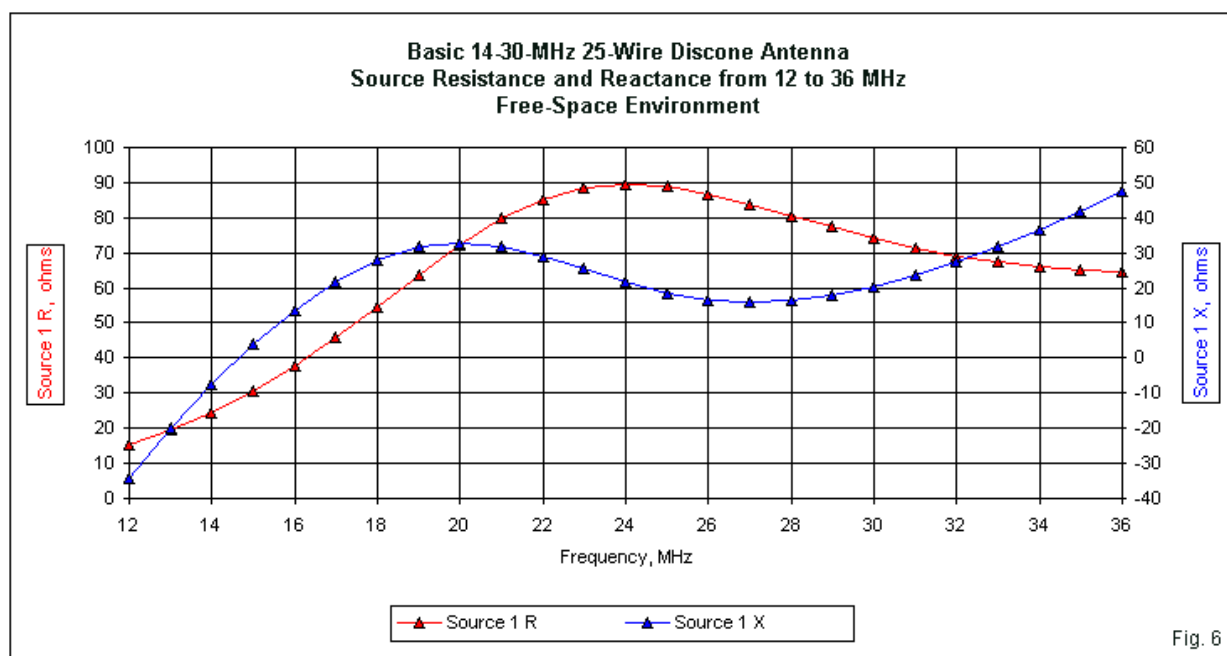
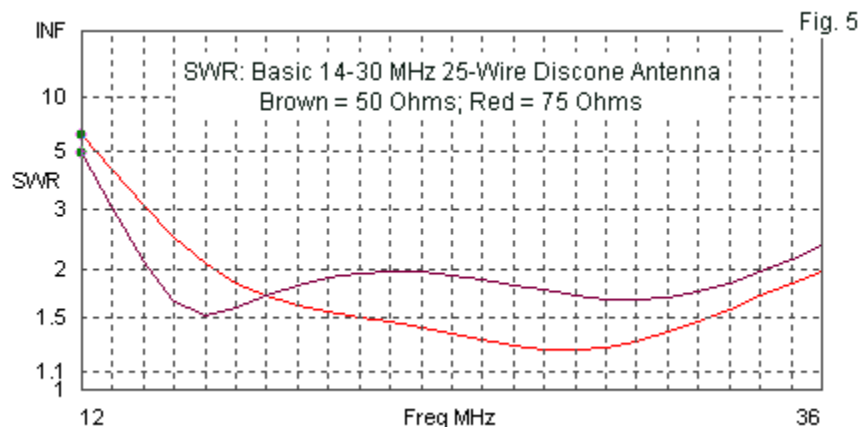
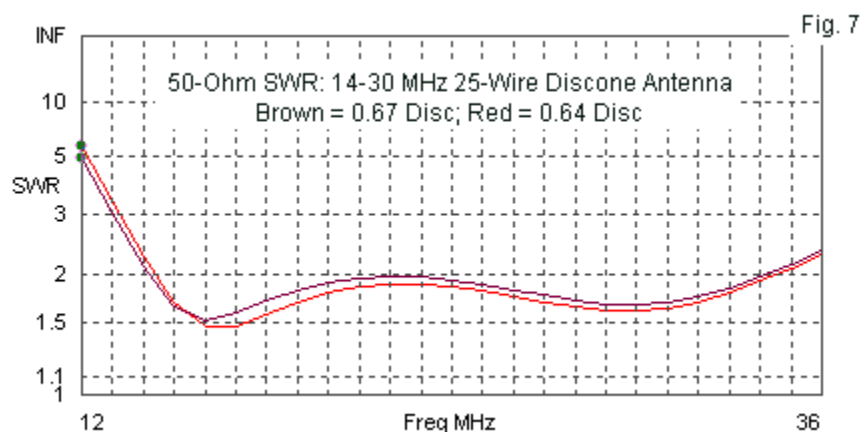


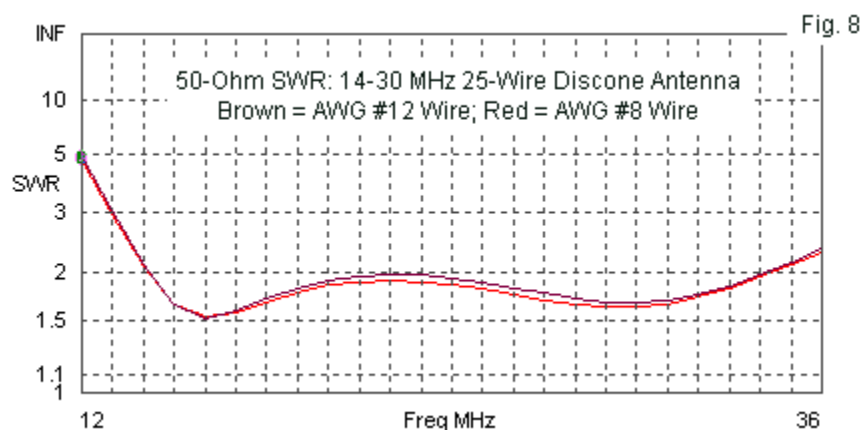
Fig. 6 provides curves for the resistance and reactance across the passband. Note that the reactance is always inductive for this model. It almost reaches zero at 12 MHz, but the source resistance at this frequency is too low to yield a low SWR. The source resistance peaks about mid-band (about 24 MHz) and then declines. However, the reactance describes a more complex curve. The result is a 50- Ω SWR curve with two minimum-value regions, but a 75- Ω curve with only a single minimum region.

We may reduce the mid-band (21-MHz) resistance and reactance by reducing the disc diameter to about 6.5' (about 0.64 of the open-cone diameter). However, mid-band values can be illusory. **Fig. 7** overlays the 50- Ω SWR curves for the two sizes of disc that we have so far examined, one that is 0.64 times the cone diameter, the other that is 0.67 times the cone diameter. The effect of reducing the disc diameter is essentially to shorten the overall antenna if we were to treat it as a dipole. The shorter overall length results in an SWR curve that moves upward in frequency without changing its essential shape. Therefore, an alternative strategy to increasing the overall dimensions of the array might be to simply increase the disc diameter

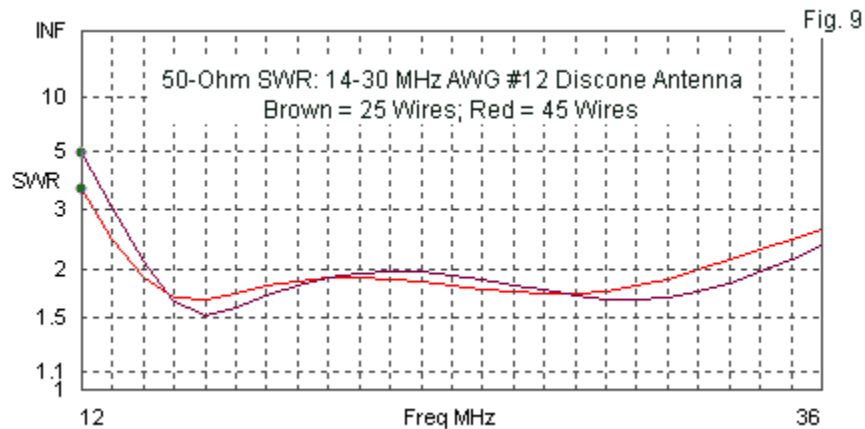
rather than reducing it. However, to do so would increase the general level of the impedance. As the figure shows, the smaller disc of the two shown results in impedance values slightly closer—overall—to 50 Ω .



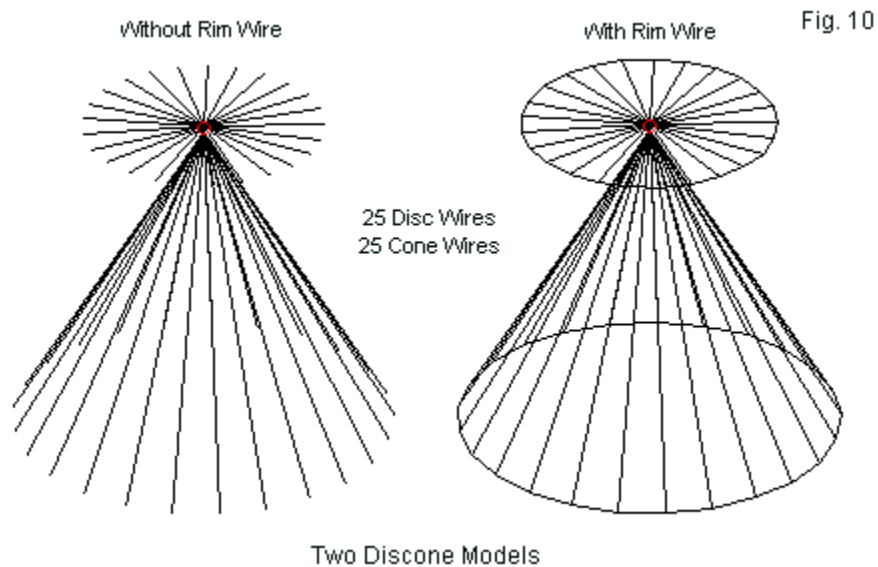
The fundamental equations for creating a discone antenna rested on the use of solid surfaces for both the disc and the cone. The basic model of the discone uses 25 AWG #12 wires. One way to improve the solidity of both surfaces is to increase the wire size. As a sample of the effect, we may replace all of the wires with AWG #8 wire. Its 0.1285" diameter is about 1.6 times fatter than the #12. **Fig. 8** shows what happens to the 50- Ω SWR passband as we use this method of solidifying the surfaces with increasing the wire count. The net effect is to slightly reduce the feedpoint resistance and reactance across the passband, resulting in a curve that is very slightly closer to ideal SWR values across the operating passband. Any shift in the passband limits is visually indistinct. Very likely, this tactic is not worth the extra weight produced by the fatter wires.



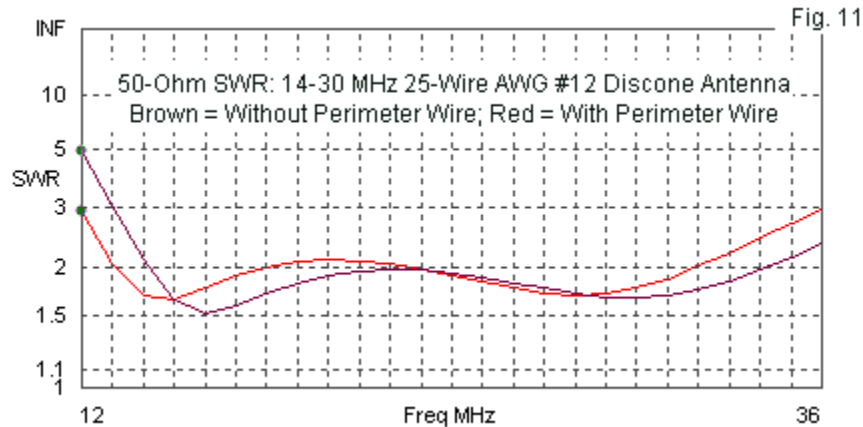
If we are going to increase the weight of the array, we might have more luck simply increasing the number of AWG #12 wires. Let's increase the count in both the disc and the cone to 45. **Fig. 9** shows what happens. Nearly doubling the number of wires closes the surfaces to a higher degree than fattening the wires. As a result, the overall passband reduces the frequency of both the upper and lower limits. The upper limits is now about 32 MHz, while the lower limit is below 14 MHz, with a shallower upswing in the SWR blow that frequency. With 45 AWG #12 wires, the total structure is actually lighter than the 25-wire AWG #8 version.



A final tactic, short of altering the fundamental antenna dimensions, is to add perimeter wires to the open end of the cone and to the disc. **Fig. 10** shows the outline of the models without and with perimeter wires, using the 25- AWG #12 structure as a basis. Besides creating optical conundrums, as one's eyes shift from one possible perspective to the other, the outlines show an important fact about the antenna dimensions. The effective length of the individual wires in both the disc and the cone increase by approximately half the length of any perimeter wire connecting adjacent radial wires.



Of all the tactical moves that we have made, adding a rim or perimeter wire to both the disk and the cone have the most extreme effect. As shown in **Fig. 11**, the perimeter wire is equivalent to increasing the dimensions of both parts of the antenna. The lower minimum region for the 50-Ω SWR values drops by over a full MHz, with a proportional drop to the upper limit of the passband. In addition, just as we saw when increasing the wire count to 45, the overall level of the source resistance increases, although the reactance values tend to remain stable. The net effect is to push the middle operating range to SWR values slightly higher than the desired 2:1 limit. Adding the rim wires does change the interactions between antenna sections. However, the models do not clearly identify which interactions occasion the rise in the feedpoint resistance.



These sample comparative SWR curves provide insight into the general trends in the passband properties of HF discone antennas with sundry variations on the structure. Due to limitations in the modeling of the discone antenna, the curves do not provide necessarily precise values, but the general trends are inherent in the structures. Perhaps the one lesson of the exercise is that it may be better to error in dimensional calculations on the side of a frequency lower than the lowest operating frequency, since the upper end of the operating curve has ample margin for shrinkage above the highest frequency in a 2:1 operating frequency range.

Other Performance Data

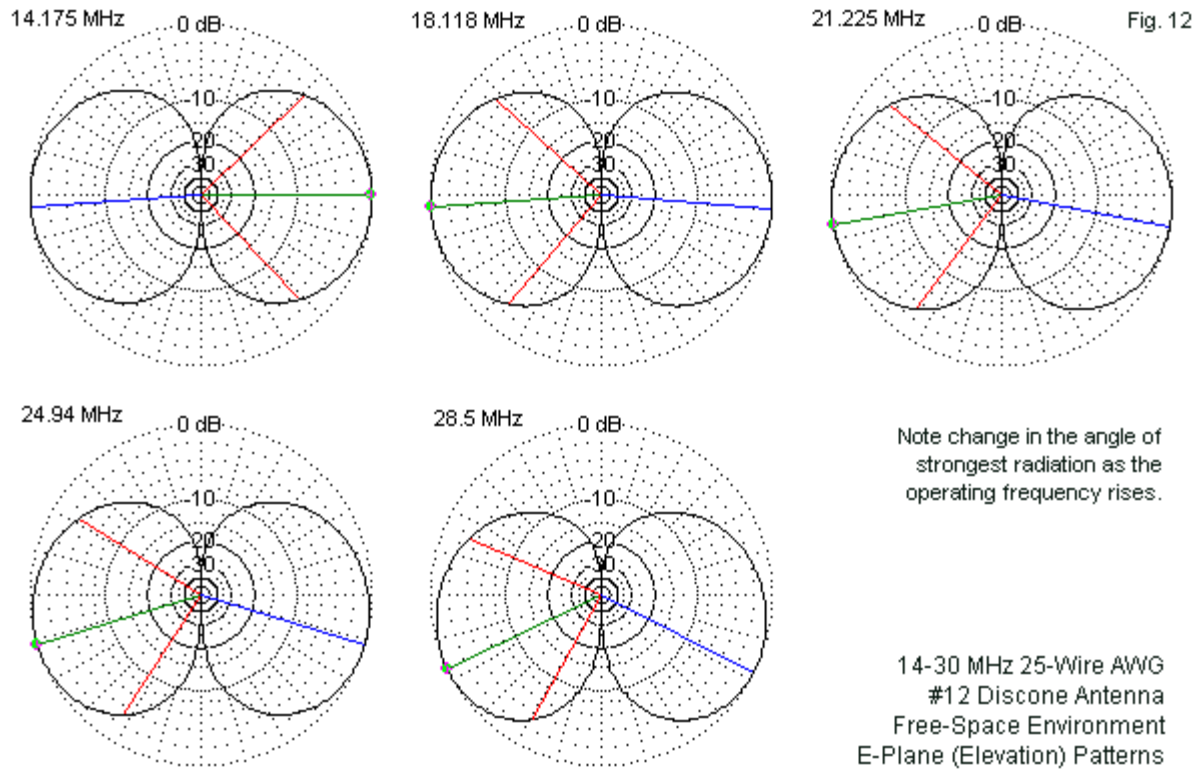
Although small variations in structure make a difference to the operating passband with respect to the feedpoint impedance, they have virtually no effect upon the pattern shape or gain of the antenna. The differences amount to those we might encounter by changing the length of a 20-meter dipole a few inches; that is, they are negligible. The comparison is apt when we consider that the discone is as basic antenna as a dipole or an elevated monopole with symmetrical radials.

The SWR curves employed a free-space environment (as well as lossless wire to facilitate accurate AGT values). I shall assume that the 14-30-MHz 25-wire AWG #12 discone is for service on the upper HF amateur bands. **Table 1** lists the modeled performance values for the center of each band.

Table 1. Free-space performance of the AWG #12 25-wire discone

Frequency MHz	Gain dBi	Tilt Angle degrees	Feedpoint Z R +/- jX Ω
14.175	1.71	0	25.5 - j 5.4
18.118	1.70	-6	55.6 + j28.6
21.225	1.72	-10	81.1 + j31.3
24.95	1.84	-17	89.0 + j18.7
28.5	2.14	-26	79.0 + j16.9

The gain values are consistent with those we might obtain from an elevated $\frac{1}{4}$ - λ monopole. The feedpoint impedance values coincide with selected points along the curves in **Fig. 6**. The only values requiring further explanation are the Tilt Angle numbers. **Fig. 12** provides a gallery of free-space H-plane patterns that illustrate the tilt angle of the high-gain bearing.



As the discone's frequency of operation increases, the pattern tilts downward, defined as the direction away from the top disc. As the operating frequency increases, the disk radius becomes a larger fraction of a wavelength. Its interactive effect upon the overall pattern is reflective in the sense of bending the pattern away from its surface. How much effect it has on the operational patterns of the HF discone over ground will require further work to evaluate.

The first step in this process is to examine the patterns of the discone over ground. For this task, I have selected three top heights: about 25', 35', and 45'. The actual heights are 0.37' higher. The corresponding bottom heights above ground are 7.43', 17.43', and 17.43'. **Fig. 13** outlines the three set-ups to provide perspective on the array size vs. its height above ground. The blue line is a stand-in for a substantial support system.

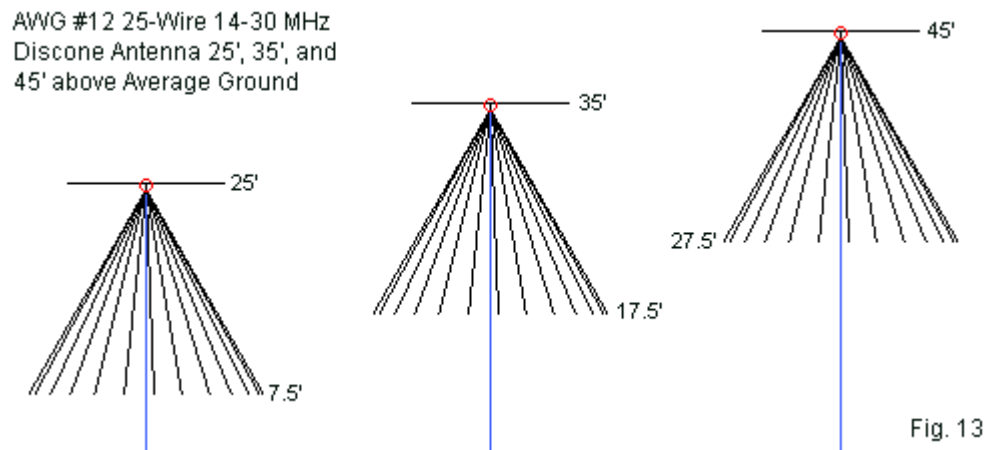


Table 2 provides the band-by-band data for each height. The gain and take-off (TO) angle data have two entries, one for maximum gain and the other for the gain of the lowest detectable lobe. The second pair of columns only has entries when they differ from the values in the first column pair. The table records the modeled feedpoint impedance data in order to provide for comparisons both with the corresponding information in **Table 1** and among the three heights listed in the table. All values are for average ground (conductivity 0.005 S/m, permittivity 13).

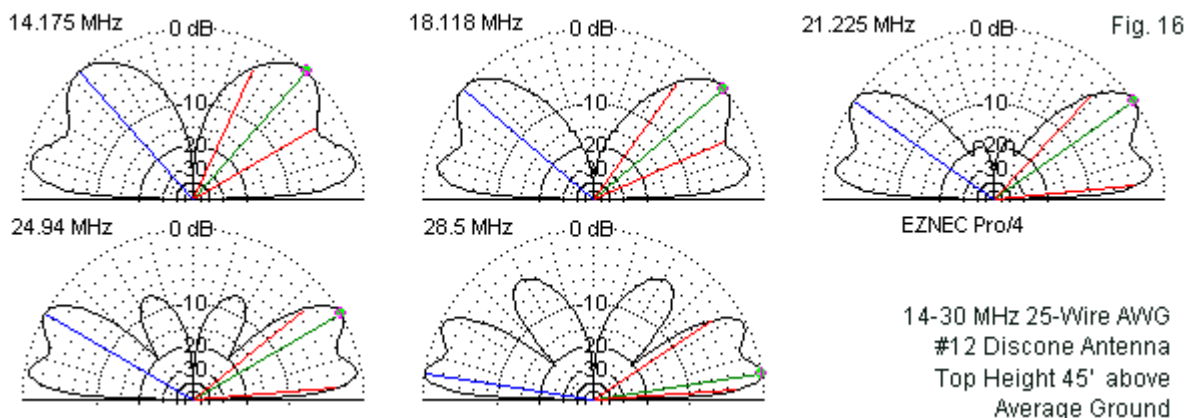
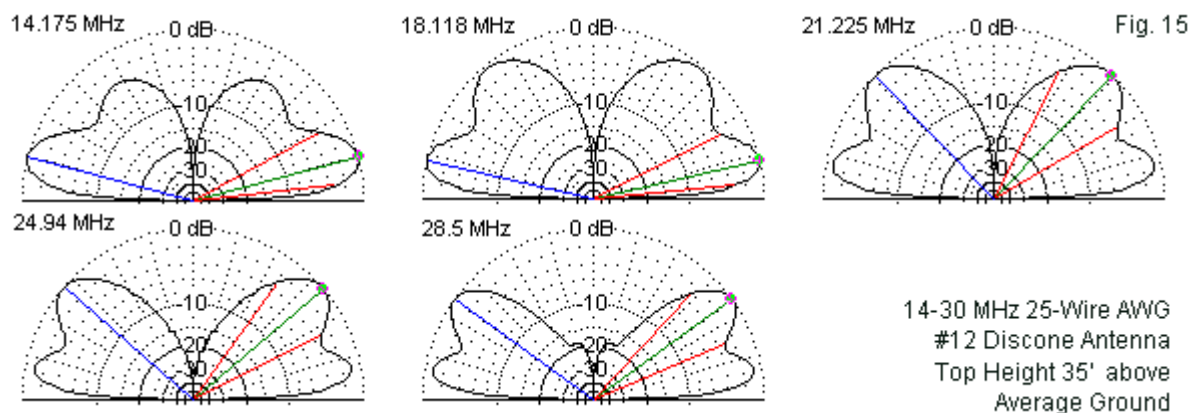
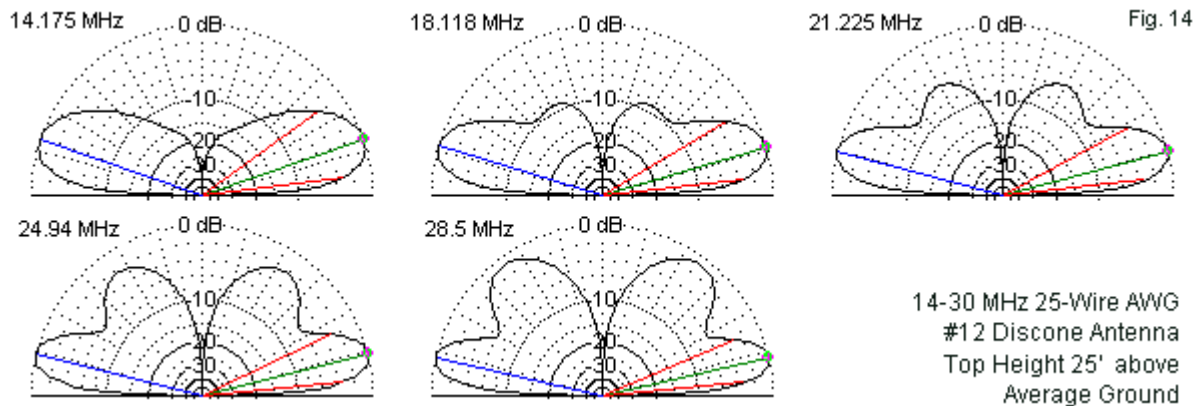
Table 2. Performance of the AWG #12 25-wire discone at three top heights above average ground

Frequency MHz	Max. Gain dBi	TO Angle degrees	Low-Lobe Gain dBi	TO Angle degrees	Feedpoint Z R +/- jX Ω
A. 25'					
14.175	0.41	19			26.2 – j10.2
18.118	0.64	16			48.8 + j26.1
21.225	0.63	15			75.3 + j38.5
24.94	0.38	14			96.7 + j24.9
28.5	-0.07	13			85.6 + j10.9
B. 35'					
14.175	0.69	15			23.4 – j 5.6
18.118	0.62	13			56.2 + j31.7
21.225	1.24	46	0.54	12	85.0 + j30.1
24.94	1.61	40	0.56	11	86.4 + j15.8
28.5	1.51	36	0.71	10	76.8 + j19.7
C. 45'					
14.175	1.03	48	0.54	13	25.5 – j 4.2
18.118	2.14	40	0.85	12	56.7 + j27.3
21.225	2.42	35	1.32	11	79.1 + j30.8
24.94	2.25	30	1.75	10	90.3 + j20.4
28.5	1.87	9	0.71		79.6 + j15.1

Those unfamiliar with the development of lobes in vertical antennas at various heights above ground may find the table somewhat mystifying. Therefore, **Fig. 14, 15, and 16** provide galleries of elevation patterns for the antennas at each height and frequency. The plots allow you to correlate the data to the pattern shapes involved.

The pattern shapes are largely functions of three interactive factors. First is the height of the antenna (normally measured at the feedpoint, that is, the region of highest current) above ground as a fraction of a wavelength. We may raise the antenna height physically or introduce a second factor: raising the operating frequency. As we do either, we find that an initial single elevation lobe develops into a two-lobe structure. Further increases in height eventually yield a condition in which the second elevation lobe is stronger than the lowest lobe. That condition produces the need to supply additional information on the lowest lobe to permit an evaluation of potential performance at low elevation angles that favor HF skip-communications.

The ground is the third factor. As operating frequency increases for a given antenna height (as a fraction of a wavelength), ground losses also increase. Increasing the antenna height goes some distance in counteracting this final condition. Therefore, we shall find differences in the reported gain of the antenna at different heights and frequencies, even though the pattern shapes and TO angles may be similar.



The function of the tables and pattern galleries is not to reach judgmental conclusions about the subject HF discone antenna. Rather, the goal is to provide data that may allow a prospective builder to decide in advance whether any of the pattern sets are usable for projected communications objectives and which height may be best among the possibilities.

Comparative Possibilities

Constructing an HF discone antenna requires a considerable amount of material, planning, and care, whatever the final dimensions. Before committing to such a project, the potential user

should be aware of how the anticipated performance compares with other candidates for the job of covering 20 through 10 meters. We shall look at only 3 possibilities, and then only generically. Actual implementations—whether homemade or commercial—may vary in performance for a large number of reasons. **Fig. 17** shows the range of our candidates.

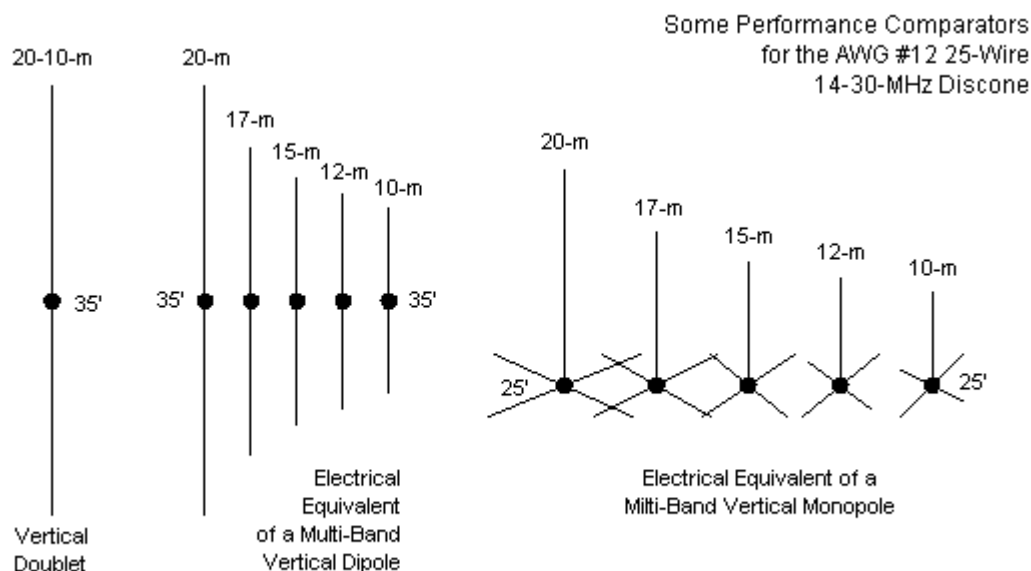


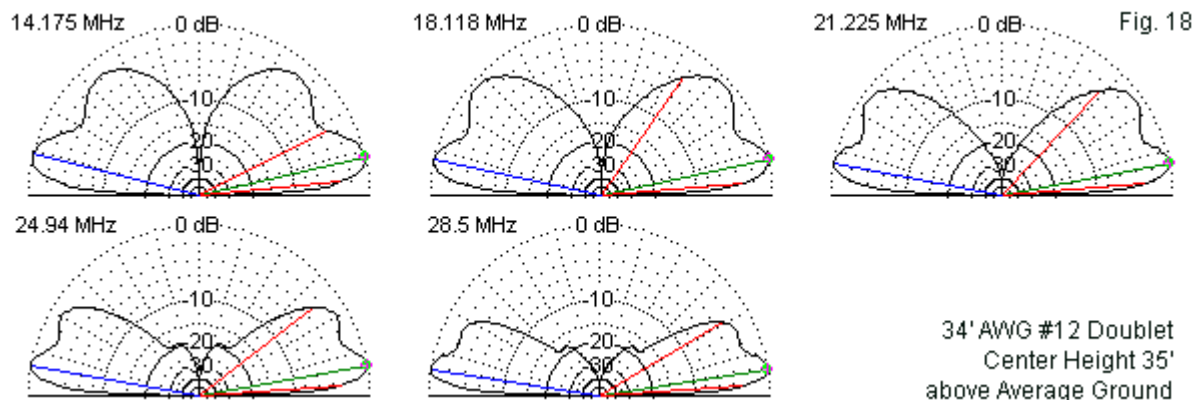
Fig. 17

We shall look at a very simple structure, a center-fed doublet just long enough to be self-resonant in the 20-meter band. Next, we shall explore multi-band $\frac{1}{2}\lambda$ dipoles, that is, antennas that are self-resonant on each of the upper HF bands by virtue of using stubs and other devices to obtain dipole performance. Finally, we shall look at $\frac{1}{4}\lambda$ multi-band monopoles. In practice, these antennas are usually equipped with traps to obtain $\frac{1}{4}\lambda$ performance as measured from the feedpoint upward along the vertical element. In both latter cases, we shall use individual antenna models to estimate the likely performance, ignoring any losses and other aberrations created by the means of obtaining resonant operation on each band. The results will not be the performance obtainable from one or another commercial antenna, but only a ballpark estimate.

The Vertical Doublet: Let's set up a center-fed vertical doublet that is just long enough to count as a $\frac{1}{2}\lambda$ dipole on 20 meters. 34' of AWG #12 copper wire will do the job. The center feedpoint will be at the 35' level, equal to the level of the feedpoint for the middle-level discone antenna. The antenna wire will therefore extend from 18' above ground to a top height of 52'. **Table 3** provides the modeling data for this antenna.

Table 3. Performance of a vertical doublet fed at 35' above average ground

Frequency MHz	Max. Gain dBi	TO Angle degrees	Low-Lobe Gain dBi	TO Angle degrees	Feedpoint Z R +/- jX Ω
14.175	0.90	13			73 + j16
18.118	1.48	12			183 + j461
21.225	2.17	11			416 + j935
24.94	3.13	10			1639 + j1804
28.5	4.12	9			3438 - j1746



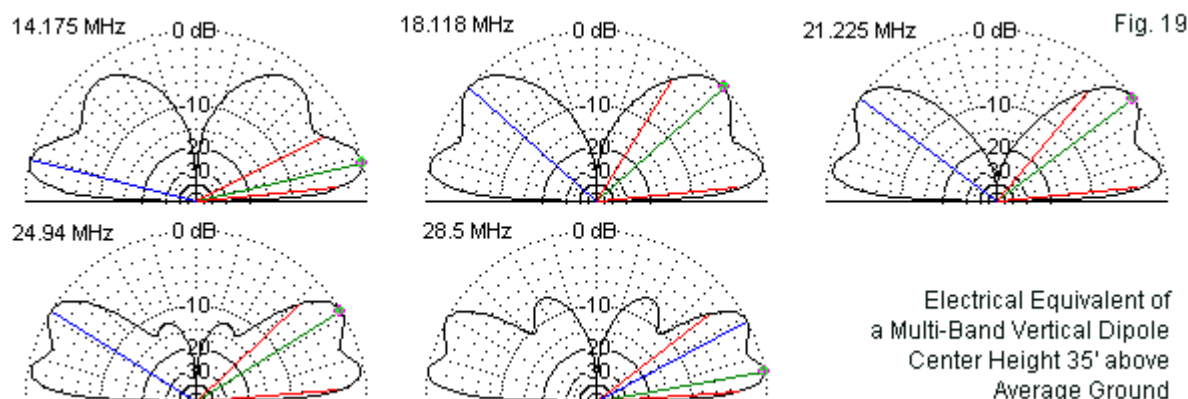
The gallery of elevation patterns for the doublet shows why the doublet requires no low-lobe entries and why the gain values increase as the frequency increases. As the user increases the operating frequency, the doublet becomes longer as a fraction of a wavelength. At the middle of 10 meters, the antenna is slightly longer than $1-\lambda$. As we increase the length of a center-fed doublet, the beamwidth narrows and the resulting gain in the main lobe increases. These natural actions of the antenna keep the lowest lobe as the strongest lobe, despite the fact that the rising feedpoint shows the emergence of the third elevation lobes at 12 and 10 meters. The discone antenna with a top height of about 35' held the gain in the lowest lobe to a very consistent value—between 0.54 and 0.71 dBi—at comparable elevation angles to those of the vertical doublet.

The doublet is perhaps the mechanically simplest antenna that we might use. Implementations might use tubing amenable to simple rope guys along with a lower non-conductive post. However, the doublet also shows an extreme range of impedances, some with very high reactive components. Hence, the antenna would require parallel feedline used in conjunction with a wide-range antenna tuner. Routing the feedline and adding protections against common-mode currents in the shack are two common problems associated with the vertical doublet. Nevertheless, assuming that one may overcome these difficulties, the antenna would outperform the discone on all bands and save considerable time, energy, and money related to construction.

Resonant $\frac{1}{2}\lambda$ Dipoles: There are a number of commercially made antennas that claim to have the performance of resonant dipoles on all operating bands. The methods of implementation vary, but some are usable in elevated operating positions. Therefore, as a second comparison, let's create a series of such dipoles and place them so that the feedpoint is at 35'. The models will again use AWG #12 copper wire, although most commercial versions of these antennas use aluminum tubing. The results are idealized, as shown in **Table 4**.

Table 4. Performance of vertical dipoles, each fed at 35' above average ground

Frequency MHz	Max. Gain dBi	TO Angle degrees	Low-Lobe Gain dBi	TO Angle degrees	Feedpoint Z R +/- jX Ω
14.175	0.89	13			70 - j0
18.118	1.32	42	1.22	12	73 + j0
21.225	2.11	37	1.65	11	74 - j0
24.94	2.62	32	2.27	11	73 - j0
28.5	2.77	10			72 + j2



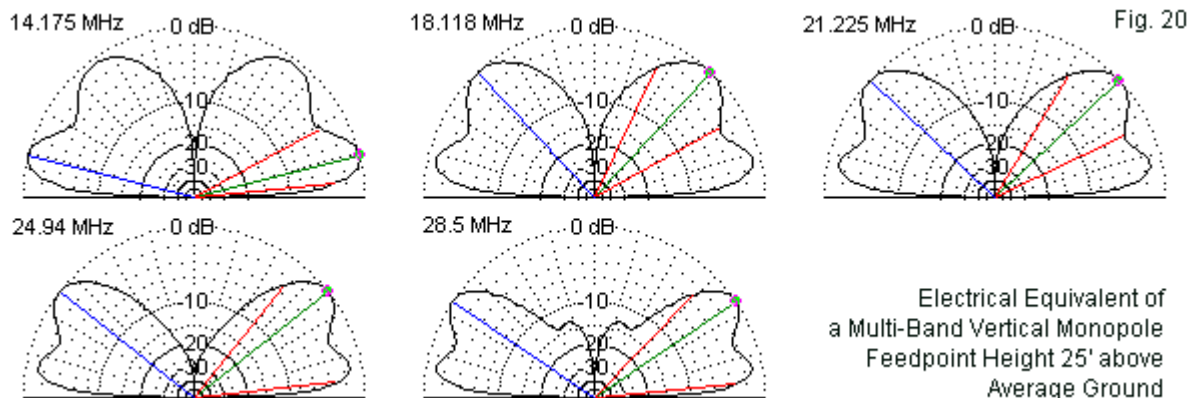
As shown in **Fig. 19**, the patterns for the dipoles with a constant 35' feedpoint do not benefit from the narrowing beamwidth that comes with electrically lengthening the element. Hence, they all exhibit (in free-space) the 80° beamwidth that provides sufficient energy to give the second elevation lobe dominance on the 3 middle bands of the HF set. Still, the lowest lobe of the dipole set manages to provide more gain than the discone on the lowest lobe, the one of highest interest for skip communications.

Structurally, the multi-band dipole is simpler mechanically than the discone, but the required matching systems to achieve resonance on each band may in fact be outside the reach of many antenna builders. As well, the variety of means by which commercial multi-band dipoles achieve resonance may not always produce true dipole patterns. Nevertheless, for the savings in labor and maintenance, a multi-band dipole offers an attractive alternative to the HF discone.

The Trap Multi-Band Monopole: We shall simulate a multi-band $\frac{1}{4}$ - λ monopole and radials with a set of individual $\frac{1}{4}$ - λ monopoles. In each case, the AWG #12 copper wire models will set the radials at 25' above ground, the average height for roof mounting. The top height of the 20-meter monopole is about 43', just above the level of the middle discone, but its feedpoint is 10' lower than the more complex structure. All of the impedance values will be low because each monopole uses equal lengths for the vertical element and the 4 radials in each model. Commercial antennas go to great design lengths to achieve values closer to 50 Ω at the feedpoint on each band. The performance values would not change by very much, and the models will ignore any losses associated with traps or other means of obtaining resonance on each upper HF band. The idealized data appears in **Table 5**.

Table 5. Performance of vertical monopoles, each fed at 25' above average ground

Frequency MHz	Max. Gain dBi	TO Angle degrees	Low-Lobe Gain dBi	TO Angle degrees	Feedpoint Z R +/- jX Ω
14.175	0.39	14			22 + j2
18.118	1.41	47	0.51	13	23 + j3
21.225	2.00	43	0.72	12	24 + j2
24.94	2.51	38	1.21	12	23 + j1
28.5	2.67	34	1.58	11	23 + j2



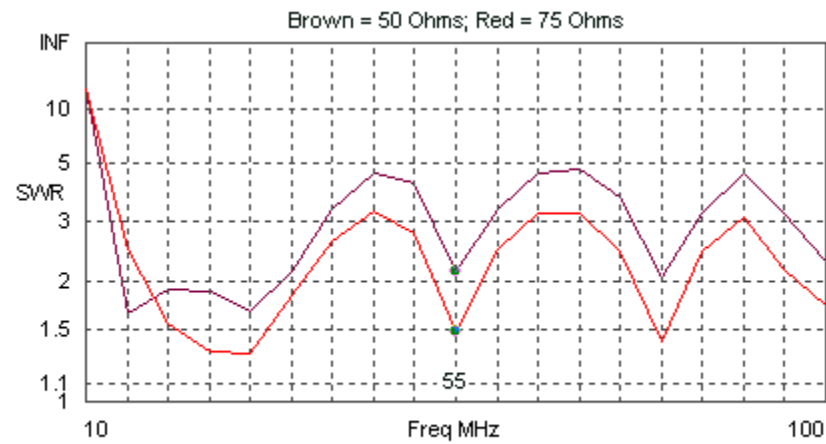
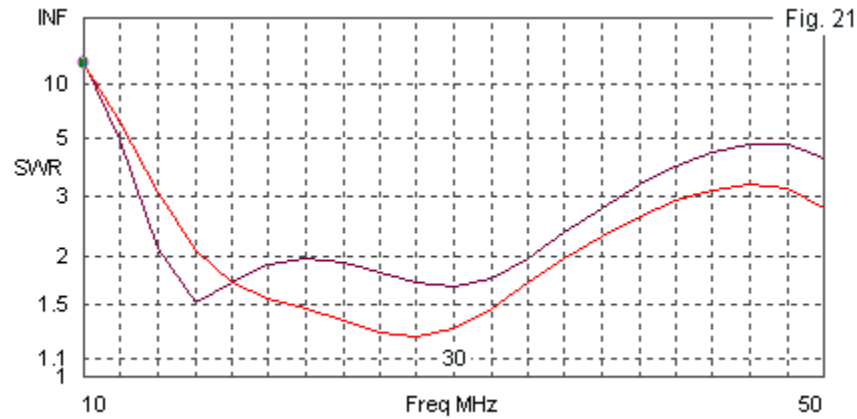
The elevation plots in **Fig. 20** show the degree to which higher elevation lobes dominate performance on most bands with a rooftop monopole. If we compare the data for the 35' discone and the monopoles, we discover that the values are very similar for the lowest lobe on the lower three bands. On the upper two bands, the lowest monopole lobes show superior performance. Of course, the monopole values do include losses from the means of obtaining resonant performance.

Multi-band vertical monopoles for rooftop mounting, with a requisite small set of radials, are so readily available in commercial form that few amateurs construct their own versions. In general, the structures are relatively simple, easy to support, and require little maintenance (although antenna maintenance should be a regular part of every amateur operator's twice-yearly schedule). Hence, they remain perhaps the most dominant form of vertical antenna used with amateur stations.

The HF discone—at least the version used as the primary focus of these notes—has one major feature that the multi-band dipoles and monopoles lack: the ability to function effectively outside each amateur band over the range for which the design is rated. To achieve the goal of obtaining similar performance across a wide frequency span (2:1 in the model shown) the construction challenges are considerable. One might do well to examine the versions shown in Belrose' 1975 *QST* article or the pair of discs created Daniel Krupp, W8WNF, in his article in Volume 5 of *The ARRL Antenna Compendium*.

Extended Frequency Performance

VHF-UHF discs often carry service frequency ranges considerable larger than the 2:1 range of the subject model shown in these notes. Before we close, we might take a brief look at what happens to the AWG #12 wire discone intended to cover 14 to 30 MHz when we push the range upward. We should keep in mind that the precise numbers associated with the SWR values in **Fig. 21** may not be those of the model, although the model will be accurate enough to indicate the general trends involved. The figure provides two SWR curve sets, one with an upper limit of 100 MHz, the other limited to 50 MHz. In both cases, the graphs provide values for both 50-Ω and 75-Ω reference levels. Except at the lowest end of the range, the 75-Ω curves show the lower values. For extended-frequency service, the 75-Ohm curves may prove to be the more useful, since their peak values rarely exceed 3:1. If we assume that the modeled values are higher than we might obtain with a well-adjusted physical prototype, the peak values would decline even further.



Expanded 50- and 75-Ohm SWR Plots: AWG #12 25-Wire Discone Antenna

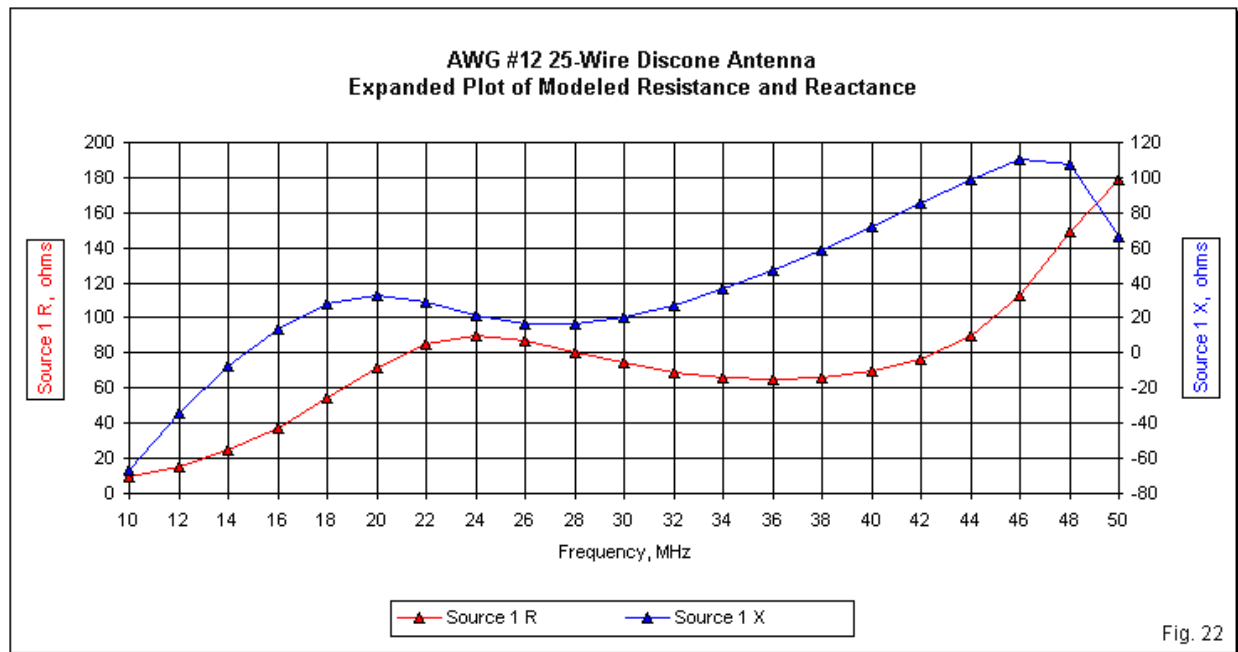
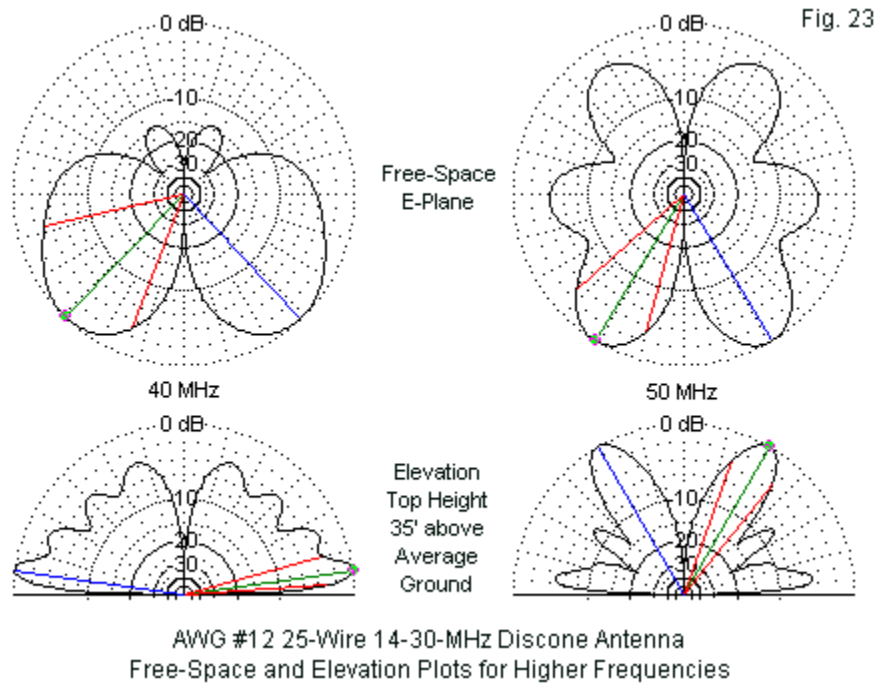


Fig. 22

The curves for 10 through 50 MHz extend the range of earlier curves that stopped at 30 MHz. They suggest that perhaps with judicious design work, we might be able to tame the

discone for a 4:1 to 5:1 frequency range. Based on Belrose' measurements for his 40-meter base-line discone, such ranges are entirely feasible. The chart of modeled values of feedpoint resistance and reactance in **Fig. 22** suggest that finding a means of limiting both the resistance and the reactance values at the upper end of the expanded passband might achieve the goal. Changing the spacing between the disc and the cone—a task that modeling does not permit within the range of acceptable AGT scores—might alter the interactions sufficiently to reduce these values.

If we allow that extending the SWR performance is feasible, the remaining question is whether we obtain good antenna performance in the process. **Fig. 23** provides a general idea of what happens as we extend the operating frequency and therefore extend the element length of the cone to more than an electrical $5/8\lambda$.



The upper patterns are free-space E-plane patterns for 40 and 50 MHz for the very same model that we have used throughout these notes. In **Fig. 12**, we noted a pattern tilt angle (away from the disc) that increased as we raised the operating frequency. The process continues with further increases in the operating frequency. At 40 MHz, the angle is 47° below the line marking a true dipole-type bidirectional free-space pattern. At 50 MHz, the angle increases to 59° , with a second set of lobes forming to the disc side of the antenna.

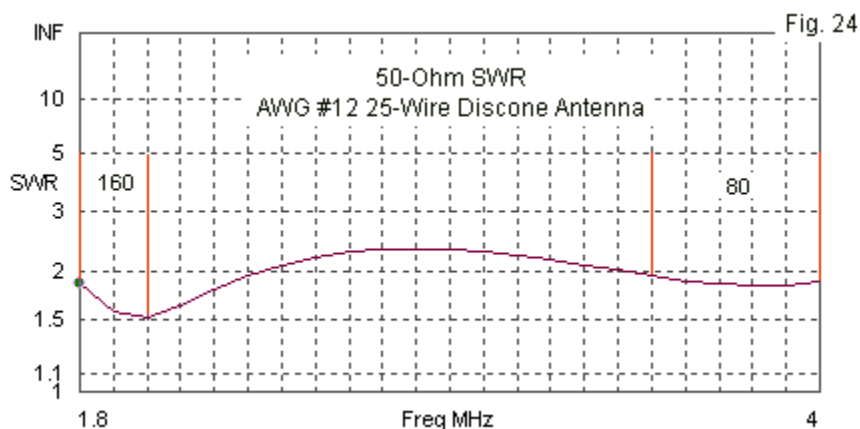
When we place the antenna 35' at its top above average ground, we obtain patterns that combine incident and reflected rays. At 40 MHz, the result is a weak lowest lobe (0.31 dBi) compared to many other antenna types one might use for vertically polarized service in this range. At 50 MHz, high-angle radiation dominates the pattern, although at a 7° elevation angle, the gain is still about 1.3 dBi. These patterns suggest that there is very little reason—and even less good reason—to push the operating span of a wire discone antenna much beyond a 2:1 frequency range.

Conclusion

Summarizing our findings is a difficult task. First, we have looked at wire discons for the upper HF range as perhaps the most promising structural and frequency region for the purposes of obtaining reasonably accurate models. Despite some uncertainties about the precision of the models with respect to correlating model impedance values with those one might obtain from a physical implementation, the primary models revealed the general trends that hold for the discone. Less critical were the constraints on modeling performance, since the antenna is a basic antenna and not a complex array of antenna elements. In this arena, we were able to develop reasonable performance expectations for the antenna at various heights above ground. In the process, we noted that the discone is subject to the same upper lobe development rules that apply to antennas with more limited frequency ranges.

When we compared the discone to some other types of multi-band antennas, we discovered that the critical performance of the discone's lowest lobe only matched or fell below the levels of performance obtained from the comparators. The chief merit of the discone appears to be its ability to operate consistently across a 2:1 or slightly greater range of frequencies. When we press operations beyond these limits, even if we obtain adequate impedance performance, we obtain less-than-desirable patterns.

In the end, a discone for frequencies below the VHF bands is a project for those with special needs (such as coverage between amateur bands) or for those who simply like to meet a construction challenge of very high proportions. Perhaps the one region that might best benefit from a discone antenna includes the 160-meter and 80/75-meter amateur bands. **Fig. 24** shows the 50- Ω SWR curve for a free-space scaled version of the primary model—still using AWG #12 wire—with the two amateur bands marked.



The antenna would be over 141' tall, plus allowance for ground clearance. The disk has a radius of nearly 55', while the cone opening has a radius of nearly 82'. Such an antenna would indeed cover both bands, but the construction hurdles might challenge the most inveterate wire antenna aficionado.

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(54) **BROADBAND TERMINATED DISCONE ANTENNA AND ASSOCIATED METHODS**

BREITBANDABGESCHLOSSENE DISCONE-ANTENNE UND DIESBEZÜGLICHE VERFAHREN
ANTENNE DISCÔNE LARGE BANDE À TERMINAISON ET PROCÉDÉS ASSOCIÉS

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(73) Proprietor: **Harris Corporation
Melbourne, FL 32919 (US)**

(72) Inventor: **PARSCHE, Francis, Eugene
Palm Bay
FL 32905 (US)**

(74) Representative: **Schmidt, Steffen J.
Wuesthoff & Wuesthoff
Patent- und Rechtsanwälte
Schweigerstrasse 2
81541 München (DE)**

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Description

[0001] The present invention relates to the field of antennas, and more particularly, this invention relates to low-cost broadband antennas, omnidirectional antennas, conical antennas, folding and related methods.

[0002] Modern communications systems are ever more increasing in bandwidth, causing greater needs for broadband antennas. Some may require a decade of bandwidth, e.g. 100-1000 MHz. Some needs (e.g. military needs) may require broadband antennas for low probability of intercept (LPI) transmissions or communications jamming. Jamming systems can use high power levels and the antenna must provide a low voltage standing wave ratio (VSWR) at all times. The bandwidth need may be instantaneous, such that tuning may not suffice.

[0003] In the current physics, antenna size and instantaneous gain bandwidth may be limited through a relationship known as Chu's Limit (L. J. Chu, "Physical Limitations of Omni-Directional Antennas", Journal of Applied Physics, Vol. 19, pp 1163 - 1175 Dec. 1948). Under Chu's Limit, the maximum 3 dB gain fractional bandwidth in single tuned antennas cannot exceed $200 (r/\lambda)^3$, where r is the radius of a spherical envelope placed over the antenna for analysis, and λ is the wavelength. While antenna instantaneous gain bandwidth is fundamentally limited, voltage standing wave ratio (VSWR) bandwidth is not. Thus, in some systems it may be necessary to trade away gain for increased VSWR bandwidth by introducing losses or resistive loading. Losses are required when the antenna must operate beyond Chu's relation, that is, to provide low VSWR at small and inadequate sizes. Without dissipative losses, the single tuned 2 to 1 VSWR bandwidth of an antenna cannot exceed $70.7 (r/\lambda)^3$.

[0004] Multiple tuning has been proposed as an approach for extending instantaneous gain bandwidth, e.g. with a network external to the antenna, such as an impedance compensation circuit. Multiple tuned antennas have complex polynomial responses, rippled like a Chebyshev filter. Although beneficial, multiple tuning cannot be a remedy to all antenna size-bandwidth needs. A simple antenna may provide a "single tuned" frequency response that is quadratic in nature, and Wheeler has suggested a 3π bandwidth enhancement limit for infinite order multiple tuning, relative single tuning ("The Wideband Matching Area For A Small Antenna", Harold A. Wheeler, IEEE Transactions on Antennas and Propagation, Vol. AP-31, No. 2, Mar. 1983).

[0005] The $1/2$ wave thin wire dipole is an example of a simple antenna. It can have a 3 dB gain bandwidth of only 13.5 percent and a 2.0 to 1 VSWR bandwidth of only 4.5 percent. This is near 5 percent of Chu's single tuned gain bandwidth limit and it is often not adequate. Broadband dipoles are an alternative to the wire dipole. These preferably utilize cone radiating elements, rather than thin wires, for radial rather than linear current flow. They are well suited for wave expansion over a broad frequency

range, being a self exciting horn. A biconical dipole, having for example, a conical flare angle of $\pi/2$ radians has essentially a high pass filter response from a lower cut off frequency. Such an antenna provides wide bandwidth, and a response of 10 or more octaves is achieved. Yet, even the biconical dipole is not without limitation: the VSWR rises rapidly below the lower cutoff frequency. Low pass response antennas are seemingly unknown in the present art.

[0006] Broadband conical dipoles can include dissimilar half elements, such as the combination of a disc and a cone. A "discone" antenna is disclosed in U.S. Pat. No. 2,368,663 to Kandoian. The discone antenna includes a conical antenna element and a disc antenna element positioned adjacent the apex of the cone. The transmission feed extends through the interior of the cone and is connected to the disc and cone adjacent the apex thereof. A modern discone for military purposes is the model RF-291-AT001 Omnidirectional Tactical Discone Antenna, by Harris Corporation of Melbourne, FL. It is designed for operation from 100 to 512 MHz and usable beyond 1000 MHz. It has wire cage elements for lightweight and easy of deployment.

[0007] U.S. Patent 7,170,462, to Parsche, describes a system of broadband conical dipole configuration for multiple tuning and enhanced pattern bandwidth. Discone antennas and conical monopoles may be related to each other by inversion, e.g. one is simply the other upside down. U.S. Patent Nos. 4,851,859 and 7,286,095 disclose such antennas formed with connectors at the cone and disc, respectively.

[0008] Folding in dipole antennas may be attributed to Carter, in US Pat. 2,283,914. The thin wire dipole antenna included a second wire dipole member connected in parallel to form a "fold". In Fig. 5 of U.S. Patent No. 2,283,914 the folded dipole member includes a resistor for the enhancement of VSWR bandwidth. Without the resistor, bandwidth was not enhanced (relative an unfolded antenna of the same total envelope) but there were advantages of impedance transformation and otherwise. Resistor "terminated" folded dipoles were employed in World War II. Later, in U.S. Patent No. 4,423,423 to Bush, a resistive load was described in a folded dipole fold member. Resistively terminated folded wire dipole antennas may lack sufficient gain away from their narrow resonances.

[0009] Conventional discone antennas have broad instantaneous bandwidth but rapidly rising VSWR at frequencies below cutoff. To obtain sufficiently low VSWR at low frequencies, they may be too physically large. The large size may cause insufficient pattern beamwidth at the higher frequencies, and there the pattern may droop or fall below the target. Accordingly, there is a need for a broadband antenna that provides a low VSWR at all radio frequencies, at small size, and that does not suffer from these limitations.

[0010] In view of the foregoing background, it is therefore an object of the present invention to provide an elec-

trically small communication antenna with small size, broad bandwidth, and a low VSWR at many frequencies.

[0011] This and other objects, features, and advantages in accordance with the present invention are provided by a discone antenna including a conical antenna element having an apex, a disc antenna element adjacent the apex of the conical antenna element and comprising a proximal electrically conductive planar member and a spaced apart distal electrically conductive planar member being electrically connected together at respective peripheries thereof defining a folded ground plane. An antenna feed structure is coupled to the disc and conical antenna elements and includes a first conductor coupled to the proximal electrically conductive planar member, and a second conductor coupled to the conical antenna element and to the distal electrically conductive planar member.

[0012] At least one impedance element, such as a resistive element, may be coupled between the second conductor and the distal electrically conductive planar member. The proximal electrically conductive planar member may include an opening therein, and the second conductor may extend through the opening in the proximal electrically conductive planar member to connect to the distal electrically conductive planar member. The conical antenna element defines an interior space, and the antenna feed structure may extend through the interior space to the apex of the conical antenna element. The second conductor may be connected to the conical antenna element at the apex thereof.

[0013] The first conductor and second conductor may define a coaxial transmission feed. The conical antenna element and/or the disc antenna element may comprise a continuous conductive layer or a wire structure. Furthermore, a dielectric material may be provided between the proximal electrically conductive planar member and the distal electrically conductive planar member of the disc antenna element. The proximal electrically conductive planar member and the distal electrically conductive planar member may be defined by a continuous conductive layer, such as a copper layer, surrounding the dielectric material.

[0014] The approach may be referred to as a terminated discone antenna or a resistor traded antenna which may include an impedance device such as a resistor and/or inductor placed at a fold. The approach may provide reduced gain above a cutoff frequency being traded for low VSWR below the cutoff frequency to get increased usable bandwidth.

[0015] A method aspect is directed to making a discone antenna including providing a conical antenna element having an apex, positioning a disc antenna element adjacent the apex of the conical antenna element and comprising a proximal electrically conductive planar member and a spaced apart distal electrically conductive planar member being electrically connected together at respective peripheries thereof to define a folded ground plane. The method further includes coupling an antenna feed

structure to the disc and conical antenna elements including coupling a first conductor to the proximal electrically conductive planar member, and coupling a second conductor to the conical antenna element and to the distal electrically conductive planar member.

[0016] The method may include coupling at least one impedance element, e.g. a resistive element, between the second conductor and the distal electrically conductive planar member. An opening may be formed in the proximal electrically conductive planar member, and the second conductor may be extended through the opening in the proximal electrically conductive planar member to connect to the distal electrically conductive planar member.

[0017] The conical antenna element defines an interior space, and the method may further include extending the antenna feed structure through the interior space to the apex of the conical antenna element and connecting the second conductor to the conical antenna element at the apex thereof. The method may further include providing a dielectric material between the proximal electrically conductive planar member and the distal electrically conductive planar member of the disc antenna element.

FIG. 1 is a schematic diagram of an exemplary discone antenna according to the present invention.

FIG. 2 is an enlarged view of a portion of an exemplary discone antenna according to another embodiment.

FIG. 3 is a plot of the measured elevation plane radiation patterns of the discone antenna of FIG. 1.

FIG. 4 is a plot of the VSWR response of the discone antenna of FIG. 1 compared to a conventional discone antenna, in 50ohm systems.

FIG. 5 is a plot of the measured gain on horizon of the discone antenna of FIG. 1 compared to a conventional discone antenna of the same size and shape.

FIG. 6 is a plot of size-bandwidth limitations common and fundamental to antennas, for 2:1 VSWR.

[0018] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

[0019] Referring initially to FIG. 1, a discone antenna **10** in accordance with features of the present invention will be described. The antenna **10** may be used, for example, as a VHF/UHF omnidirectional discone antenna operating between 100 to 512 MHz. The antenna **10** may be referred to as being an electrically small communication antenna with broad VSWR bandwidth. Also, the an-

tenna may be referred to as a terminated discone antenna or a resistor traded antenna which may include a resistor placed at a fold. The antenna **10** may have reduced gain above a cutoff frequency being traded for low VSWR below the cutoff frequency to get increased usable bandwidth. The term "VSWR bandwidth" generally is defined as that bandwidth over which the antenna system does not exceed a maximum value, e.g. 6:1, 2:1, or less. VSWR bandwidth may be measured at the transmitter terminals or the antenna feed points, although as used here the term VSWR can be understood to indicate VSWR at the antenna feedpoints.

[0020] The discone antenna **10** includes a conical antenna element **12** having an apex **14**. A folded disc antenna element **16** is adjacent the apex **14** of the conical antenna element **12** and includes a proximal electrically conductive planar member **18** and a spaced apart distal electrically conductive planar member **20** being electrically connected together at respective peripheries **P** thereof defining a folded ground plane. Peripheries **P** may be for instance, a plated edge. An antenna feed structure **22** is coupled to the conical and folded disc antenna elements **12**, **16** at driving points **28**, **29**, as are common to antennas. An antenna feed structure **22**, such as but not limited to a coaxial cable, includes a first conductor **26** coupled to the proximal electrically conductive planar member **18**, and a second conductor **24** coupled to the conical antenna element **12** and to the distal electrically conductive planar member **20**.

[0021] At least one impedance element **30**, such as a resistive element **32**, is illustratively coupled between the second conductor **24** and the distal electrically conductive planar member **20**, at folded node **21**. The resistive element may be a 50 ohm load resistor, for example. The proximal electrically conductive planar member **18** includes an opening **34** therein, and a portion of the second conductor **24** illustratively extends through the opening in the proximal electrically conductive planar member to connect to the distal electrically conductive planar member **20**, for example, via the resistive element **32**. The conical antenna element defines an interior space **36**, and the antenna feed structure **22** extends through the interior space to the apex **14** of the conical antenna element, as shown in the illustrated embodiment. The second conductor **24** is also illustratively connected to the conical antenna element **12** at the apex **14** thereof. A transformer **40** or similar RF impedance matching device may be included, e.g. in the antenna feed structure **22**, or interposed at driving points **28**, **29**.

[0022] The first conductor **26** and second conductor **24** define a coaxial transmission feed. Such a coaxial transmission feed includes the first conductor **26** being an inner conductor, a dielectric material **27** surrounding the inner conductor, and the second conductor **24** being an outer conductor surrounding the dielectric material, as would be appreciated by those skilled in the art.

[0023] The conical antenna element **12** and/or the folded disc antenna element **16** may comprise a continuous

conductive layer, as illustrated in FIG. 1, or a wire structure **15** cage as illustrated in the enlarged portion shown in FIG. 2, as would be appreciated by those skilled in the art. Furthermore, a dielectric material **19**, e.g. air, solid or a foam rigid material, may be provided between the proximal electrically conductive planar member **18** and the distal electrically conductive planar member **20** of the folded disc antenna element **16**. The proximal electrically conductive planar member **18** and the distal electrically conductive planar member **20** may be defined by a continuous conductive layer, such as a copper layer, surrounding the dielectric material **19**. Although not detailed, dielectric support structures may also be included with antenna **10** for structural reasons.

[0024] Referring to FIG. 1, the parameters of the example embodiment of the present invention antenna **10** are as follows: disc diameter $d_d = 0.18$ meters, cone base diameter $d_c = 0.18$ meters, height $h = 0.13$ meters, and disc thickness $t = 0.0038$ meters. The conical flare angle α was 90 degrees, making the angle between the disc and the cone 45° . Thus, a wide cone was used. Cone to disc spacing S was 2.5×10^{-3} meters. The disc dielectric fill material **19** was polyimide foam having a relative dielectric constant $\epsilon_r \approx 1.4$. The disc was covered with copper foil of 3.5×10^{-5} meters thickness, which was at least one skin depth at all frequencies above 4 MHz, and the disc peripheries **P** were copper plated to connect proximal electrically conductive planar member **18** and a spaced apart distal electrically conductive planar member **20**. Conical antenna element **12** was rolled brass and hollow. Resistive element **32** had a resistance of 50 ohms and negligible reactance. Transformer **40** was not included in the example embodiment, although one may be used if desired, as illustrated. A nominal cutoff frequency (F_c) for the example embodiment discone was 360 MHz at 6 to 1 VSWR (about 3 dB mismatch loss) in a 50 ohm system, without resistive loading element **32**. At cutoff the electrical size of the antenna was about height $h = 0.16\lambda$ and a disc diameter $d_d = 0.22\lambda$.

[0025] Measured performance of the example embodiment will now be described. A plot of the measured E plane elevation cut radiation patterns at 200 MHz, 330 MHz, 500 MHz and 1000 MHz of the discone antenna **10** of FIG. 1 are shown in FIG. 3. The measurement was taken in an anechoic chamber simulating free space. The plotted quantity is in units of dBi or decibels with respect to isotropic antenna, and the polarization of the range receive antenna was vertical, e.g. only the E_θ (vertically polarized) fields of the present invention are plotted. E_ϕ (horizontally polarized radiation) was negligible.

[0026] As can be seen, the shape of the radiation pattern of the present invention is identical or nearly identical to that of a conventional discone antenna except for the reduction of amplitude above cutoff. The azimuthal radiation pattern (not shown) for the present invention was circular and omnidirectional as is typical for sheet metal discone antennas. The null in the 330 MHz elevation cut radiation pattern ($\theta = 280^\circ$, $\phi = 0^\circ$) is as artifact formed

by the radiation from common mode currents on the exterior of the coaxial cable feed. Although this is generally beneficial, it could be eliminated with a common mode choke if desired. Pattern droop with frequency, that is the tendency of discone antennas to radiate downward along the cone flare angle, was relatively minor and about 2 decibels at 1000 MHz. This is attributed to the large conical flare angle of conical antenna element **12**.

[0027] FIG. 4 is a plot of the VSWR response **A** of the discone antenna **10** of FIG. 1 compared to the VSWR response **B** of a conventional discone antenna. That is, Fig. 4 is VSWR plot of the same discone antenna with and without resistive element **32** connected. As can be appreciated, the VSWR of the discone antenna **10** approaches 1 to 1 at zero Hz (DC), and it may be a suitable load for transmitting equipment at most or all radio frequencies. There was little rise in VSWR at 1st antiresonance (about $2F_c$) due to the wide cone used.

[0028] FIG. 5 is a plot of the measured gain **C** on horizon of the discone antenna **10** of FIG. 1 compared to the measured gain **D** in the horizontal plane and on the horizon of an identical conventional discone antenna. In other words, Fig. 5 is gain plot of the same discone antenna with and without resistive element **32** connected. The units in Fig. 5 are those of dBi or decibels with respect to an isotropic antenna. As can be seen, resistive element **32** introduces approximately 1.8 dB of gain loss in the antenna passband above cutoff, which is traded for low VSWR being obtained below cutoff.

[0029] Again, the nominal cutoff frequency for the discone antenna **10**, without the resistive element **32** was 360 MHz for 6 to 1 VSWR. Interestingly, a tiny enhancement in gain (about 0.5 dBi) was measured near the cutoff frequency when resistive element **32** was connected. This may correspond to increased directivity by modification of current distribution on the radiating structure, e.g. to a more uniform rather than sinusoidal distribution. At small electrical size the elevation plane radiation pattern of antenna **10** becomes similar to the $\cos^2 \theta$ two petal rose familiar to those in the art for $\frac{1}{2}$ wave dipoles, with some deviation for feedline radiation if transformer **40** is not of the balun type.

[0030] In a trade that would be apparent to those skilled in the art, VSWR can be reduced in most antennas by reducing gain with a resistive attenuator "pad" at the antenna feed point. The present invention is however preferential as it gives lower VSWR with less gain loss than feed point attenuation provides. As can be seen from FIG.s 4 and 5, the inclusion of resistive element **32** in discone **10** caused gain loss above cutoff to asymptotically approach 1.8 dB, while VSWR below cutoff asymptotically approached 1.0 to 1. Using 3 dB T pad attenuator at the antenna feed point instead of resistive element **32** would yield an inferior trade: 3 dB gain loss above cutoff and a VSWR greater than or equal to 3:1 asymptotically below cutoff. The folded disc antenna element **16** and resistive element **32** are thus advantaged relative a resistive element or attenuator at the antenna feed points

28, 29.

[0031] The present invention provides a resistive loading trade to meet certain (e.g. military) antenna requirements, such as e.g., spread spectrum communications or instantaneously broadband jamming. Various antennas may be required to provide low VSWR for high transmit powers, and to do at small sizes which are beyond the fundamental limitations in 100 percent efficiency instantaneous gain bandwidth, such that resistive loading is a must. The value of resistive element **32** may be adjusted to trade gain levels above cutoff against VSWR levels obtained below cutoff. Although resistive element **32** was 50 ohms in the example of the present invention, 200 ohms provides a flatter VSWR response with higher gain above cutoff, but higher VSWR below cutoff. Folded node **21** may also be connected to e.g., an inductor or capacitor, a resonant circuit or a ladder network, with or without resistive element **32**, for additional adjustment of gain and VSWR response. The driving point resistance of antenna **10** was about 10 ohms at the 330 MHz VSWR maximum when resistive element **32** was included.

[0032] At the lowest frequencies antenna **10** becomes of course very small electrically and RF current may conduct or "spill over" beyond conical antenna element **12** and onto antenna feed structure **22**, which is typically a coaxial cable. This "spill over" can be beneficial as it provides for enhancement of antenna electrical size and increased radiation. In high power systems this current should be managed for personnel safety by placing a common mode choke (balun) at a point removed from the antenna **10** but also removed from personnel, i.e. part way along the antenna mast. As will be familiar to those in the art, one type of balun is formed by winding a solenoid or helix from coax cable.

[0033] Referring to FIG. 1, antenna design parameters include the value of resistive element **32**, cone flare angle α , disc diameter d_d , and cone diameter d_c , and height h . Large cone flare angles α in conical antenna element **12** (fat cones) have the advantage of low VSWR at antiresonance ($2F_c$), as tall slender cones go in and out of resonance at octave intervals. A wide fat cone also produces less pattern droop at higher frequencies, as elevation plane pattern lobes of discone antennas can fire downwards along the cones at large electrical size. Fat cones however provide lower driving point resistances. Transformer **22** may be included to reduce VSWR near cutoff for the lower driving point/feed resistances of fatter conical antenna elements **12**.

[0034] Although the present invention antenna **10** is depicted as a "discone" antenna, with the mouth of conical element **12** downwards and the cone apex **14** upwards, it is not so limited. Present invention antenna **10** may also be inverted to operate as a "conical monopole" with the mouth of conical element **12** upwards and the cone apex **14** downwards, as can be appreciated by those skilled in the art. When antenna **10** is in the inverted or "conical monopole" orientation, some may term the folded disc antenna element **16** a folded ground plane.

Folding in antennas can be useful for the configuration of DC or "virtual grounds" for lightning, or EMP protection. For this purpose folded node **21** may be conducted to ground, e.g. by making resistive element **32** zero ohms or a wire jumper.

[0035] When antenna **10** is at great electrical size relative wavelength, e.g. at frequencies far above cutoff, the input impedance can be purely resistive and about equal to:

$$R_i = 60 \ln \cot \alpha/4$$

[0036] Where:

R_i = input impedance of antenna **10**
 α = conical flare angle (FIG. 1)

Cone angle α is thus 94 degrees for 50 ohms at great electrical size and without resistive element **32**. With resistive element **32** included, it may be necessary to make cone angle α may be made smaller as the referred value of resistive element **32** appears in parallel. The referred value of resistive element **32** to the antenna **10** driving points **28**, **29** is in general complex and varying frequency.

[0037] FIG. 6 shows the size-bandwidth limitations common to antennas, which is sometimes known as "Chu's Limit" (again, Chu, "Physical Limitations of Omni-Directional Antennas"). Curve C is for single tuning and $r/\lambda = 1/3\sqrt{[B/70.7(100\%)]}$, and curve $3\pi C$ is for infinite order multiple tuning such that $r/\lambda = 1/3\sqrt{[B/3\pi 70.7(100\%)]}$, where B is fractional bandwidth and r is the radius of an analysis sphere enclosing the antenna. Both curves are for 100 percent efficiency, which may be approximate for many discone antenna implementations. The present invention is most directed towards needs in the regions above curves, where sufficient VSWR bandwidth cannot be available from antenna structure alone due to fundamental limitation.

[0038] A method aspect is directed to making a discone antenna **10** including providing a conical antenna element **12** having an apex **14**, positioning a folded disc antenna element **16** adjacent the apex of the conical antenna element. The disc antenna element includes a proximal electrically conductive planar member **18** and a spaced apart distal electrically conductive planar member **20** being electrically connected together at respective peripheries P thereof to define a folded ground plane. The method further includes coupling an antenna feed structure **22** to the conical and folded disc antenna elements **12**, **16** including coupling a first conductor **26** to the proximal electrically conductive planar member **18**, and coupling a second conductor **24** to the conical antenna element **12** and to the distal electrically conductive planar member **20**.

[0039] The method may include coupling at least one impedance element **30**, e.g. a resistive element **32**, be-

tween the second conductor **24** and the distal electrically conductive planar member **20**. An opening **34** may be formed in the proximal electrically conductive planar member **18**, and the second conductor **24**, or at least a portion thereof, may be extended through the opening in the proximal electrically conductive planar member to connect to the distal electrically conductive planar member **20**, e.g. via resistive element **32**.

[0040] The conical antenna element **12** defines an interior space **36**, and the method may further include extending the antenna feed structure **22** through the interior space to the apex **14** of the conical antenna element **12** and connecting the second conductor **24** to the conical antenna element **12** at the apex thereof. The method may further include providing a dielectric material **19** between the proximal electrically conductive planar member **18** and the distal electrically conductive planar member **20** of the disc antenna element.

[0041] The features as described above may provide an electrically small communication antenna with broad voltage standing wave ratio (VSWR) bandwidth at most radio frequencies, even approaching zero Hz or DC. The disc antenna element provides a folded ground plane for the enhancement of VSWR bandwidth, resistive loading, for impedance conversion, and to the other purposes for which antennas are folded such as DC grounding.

Claims

1. A discone antenna comprising:

a conical antenna (12) element having an apex (14);
 a disc antenna element (16) adjacent the apex (14) of the conical antenna element and comprising a proximal electrically conductive planar member (18) and a spaced apart distal electrically conductive planar member (20) being electrically connected together at respective peripheries (P) thereof defining a folded ground plane; and
 an antenna feed structure (22) coupled to the disc and conical antenna elements including a first conductor (26) coupled to the proximal electrically conductive planar member (18), and a second conductor (24) coupled to the conical antenna element (12) and to the distal electrically conductive planar member (20).

2. The discone antenna according to claim 1 further comprising at least one impedance element (30) coupled between the second conductor (24) and the distal electrically conductive planar member (20).

3. The discone antenna according to claim 2 wherein the at least one impedance element (30) comprises at least one resistive element (32).

4. The disccone antenna according to claim 1 wherein the proximal electrically conductive planar member (18) includes an opening (34) therein; and wherein the second conductor (24) extends through the opening (34) in the proximal electrically conductive planar member to connect to the distal electrically conductive planar member.
5. The disccone antenna according to claim 1 wherein the conical antenna element (12) defines an interior space (36), and the antenna feed structure extends through the interior space (36) to the apex (14) of the conical antenna element.
6. The disccone antenna according to claim 5 wherein second conductor (24) is connected to the conical antenna element at the apex (14) thereof.
7. A method of making a disccone antenna comprising:
 - providing a conical antenna element (12) having an apex (14);
 - positioning a disc antenna element (16) adjacent the apex (14) of the conical antenna element (12) and comprising a proximal electrically conductive planar member (18) and a spaced apart distal electrically conductive planar member (20) being electrically connected together at respective peripheries (P) thereof to define a folded ground plane; and
 - coupling an antenna feed structure (22) to the disc and conical antenna elements including coupling a first conductor (26) to the proximal electrically conductive planar member (18), and coupling a second conductor (24) to the conical antenna element (12) and to the distal electrically conductive planar member (20).
8. The method according to claim 7 further comprising coupling at least one impedance element (30) between the second conductor (24) and the distal electrically conductive planar member (20).
9. The method according to claim 8 wherein the at least one impedance element (30) comprises at least one resistive element (32).
10. The method according to claim 7 further comprising:
 - forming an opening (34) in the proximal electrically conductive planar member (18); and
 - extending the second conductor (24) through the opening (34) in the proximal electrically conductive planar member to connect to the distal electrically conductive planar member.

Patentansprüche

1. Disccone-Antenne umfassend:

ein konisches Antennenelement (12), welches einen Scheitel (14) aufweist;
 ein zu dem Scheitel (14) des konischen Antennenelements benachbartes Scheiben-Antennenelement (16), welches ein nahes elektrisch leitfähiges ebenes Teil (18) und ein davon beabstandetes fernes elektrisch leitfähiges ebenes Teil (20) umfasst, die miteinander in ihren jeweiligen Randbereichen (P) derart verbunden sind, dass sie eine gefaltete Grundplatte definieren; und
 eine Antennen-Einspeisestruktur (22), die mit dem Scheiben- und dem konischen Antennenelement gekoppelt ist, umfassend einen ersten Leiter (26), der mit dem nahen elektrisch leitfähigen ebenen Teil (18) gekoppelt ist, und
 einen zweiten Leiter (24), der mit dem konischen Antennenelement (12) und mit dem fernen elektrisch leitfähigen ebenen Teil (20) gekoppelt ist.

2. Disccone-Antenne nach Anspruch 1, ferner umfassend zumindest ein Impedanzelement (30), welches zwischen dem zweiten Leiter (24) und dem fernen elektrisch leitfähigen ebenen Teil (20) gekoppelt ist.

3. Disccone-Antenne nach Anspruch 2, wobei das zumindest eine Impedanzelement (30) zumindest ein Widerstandselement (32) umfasst.

4. Disccone-Antenne nach Anspruch 1, wobei das nahe elektrisch leitfähige ebene Teil (18) darin eine Öffnung (34) umfasst; und wobei sich der zweite Leiter (24) durch die Öffnung (34) in dem nahen elektrisch leitfähigen ebenen Teil erstreckt, um mit dem fernen elektrisch leitfähigen ebenen Teil verbunden zu sein.

5. Disccone-Antenne nach Anspruch 1, wobei das konische Antennenelement (12) einen Innenraum (36) definiert und die Antennen-Einspeisestruktur sich durch den Innenraum (36) zu dem Scheitel (14) des konischen Antennenelements erstreckt.

6. Disccone-Antenne nach Anspruch 5, wobei der zweite Leiter (24) mit dem konischen Antennenelement an dessen Scheitel (14) verbunden ist.

7. Verfahren zum Herstellen einer Disccone-Antenne, umfassend:

Bereitstellen eines konischen Antennenele-

- ments (12), welches einen Scheitel (14) aufweist;
Positionieren eines Scheiben-Antennenelements (16) benachbart zu dem Scheitel (14) des konischen Antennenelements (12), wobei das Scheiben-Antennenelement ein nahes elektrisch leitfähiges ebenes Teil (18) und ein davon beabstandetes fernes elektrisch leitfähiges ebenes Teil (20) umfasst, die miteinander in ihren jeweiligen Randbereichen (P) derart elektrisch verbunden sind, dass sie eine gefaltete Grundplatte definieren; und
Koppeln einer Antennen-Einspeisestruktur (22) mit dem Scheiben- und dem konischen Antennenelement, umfassend
Koppeln eines ersten Leiters (26) mit dem nahen elektrisch leitfähigen ebenen Teil (18) und
Koppeln eines zweiten Leiters (24) mit dem konischen Antennenelement (12) und mit dem fernen elektrisch leitfähigen ebenen Teil (20).
8. Verfahren nach Anspruch 7, ferner umfassend Koppeln zumindest eines Impedanzelements (30) zwischen den zweiten Leiter (24) und das ferne elektrisch leitfähige ebene Teil (20).
9. Verfahren nach Anspruch 8, wobei das zumindest eine Impedanzelement (30) zumindest ein Widerstandselement (32) umfasst.
10. Verfahren nach Anspruch 7, ferner umfassend:
Bilden einer Öffnung (34) in dem nahen elektrisch leitfähigen ebenen Teil (18); und
Erstrecken des zweiten Leiters (24) durch die Öffnung (34) in dem nahen elektrisch leitfähigen ebenen Teil, um eine Verbindung mit dem fernen elektrisch leitfähigen ebenen Teil herzustellen.

Revendications

1. Antenne discône comprenant :

un élément (12) d'antenne conique ayant un sommet (14) ;
un élément (16) d'antenne en disque adjacent au sommet (14) de l'élément d'antenne conique et comprenant un élément (18) proximal plan électro-conducteur et un élément (20) distal plan électro-conducteur espacé étant connectés électriquement ensemble sur des périphéries (P) respectives de ceux-ci définissant un plan de sol replié ; et
une structure (22) d'alimentation d'antenne couplée aux éléments d'antenne en disque et conique incluant

un premier conducteur (26) couplé à l'élément (18) proximal plan électro-conducteur, et
un deuxième conducteur (24) connecté à l'élément (12) d'antenne conique et à l'élément (20) distal plan électro-conducteur.

2. Antenne discône selon la revendication 1, comprenant en outre au moins un élément (30) d'impédance couplé entre le deuxième conducteur (24) et l'élément (20) distal plan électro-conducteur.
3. Antenne discône selon la revendication 2, dans laquelle l'au moins un élément (30) d'impédance comprend au moins un élément (32) résistif.
4. Antenne discône selon la revendication 1, dans laquelle l'élément (18) proximal plan électro-conducteur inclut une ouverture (34) dans celui-ci ; et dans laquelle le deuxième conducteur (24) s'étend à travers l'ouverture (34) dans l'élément proximal plan électro-conducteur pour se connecter à l'élément distal plan électro-conducteur.
5. Antenne discône selon la revendication 1, dans laquelle l'élément (12) d'antenne conique définit un espace intérieur (36) et la structure d'alimentation d'antenne s'étend à travers l'espace intérieur (36) jusqu'au sommet (14) de l'élément d'antenne conique.
6. Antenne discône selon la revendication 5, dans laquelle le deuxième conducteur (24) est connecté à l'élément d'antenne conique au sommet (14) de celui-ci.
7. Procédé de fabrication d'une antenne discône comprenant :
la prévision d'un élément (12) d'antenne conique ayant un sommet (14) ;
le positionnement d'un élément (16) d'antenne en disque adjacent au sommet (14) de l'élément (12) d'antenne conique et comprenant un élément (18) proximal plan électro-conducteur et un élément (20) distal plan électro-conducteur espacé étant connectés électriquement ensemble sur des périphéries (P) respectives de ceux-ci pour définir un plan de sol replié ; et
le couplage d'une structure (22) d'alimentation d'antenne aux éléments d'antenne en disque et conique incluant
le couplage d'un premier conducteur (26) à l'élément (18) proximal plan électro-conducteur, et
le couplage d'un deuxième conducteur (24) à l'élément (12) d'antenne conique et à l'élément (20) distal plan électro-conducteur.
8. Procédé selon la revendication 7, comprenant en

autre le couplage d'au moins un élément (30) d'impédance entre le deuxième conducteur (24) et l'élément (20) distal plan électro-conducteur.

9. Procédé selon la revendication 8, dans lequel l'au moins un élément (30) d'impédance comprend au moins un élément (32) résistif. 5

10. Procédé selon la revendication 7, comprenant en outre : 10

la formation d'une ouverture (34) dans l'élément (18) proximal plan électro-conducteur ; et l'extension du deuxième conducteur (24) à travers l'ouverture (34) dans l'élément proximal plan électro-conducteur pour le connecter à l'élément distal plan électro-conducteur. 15

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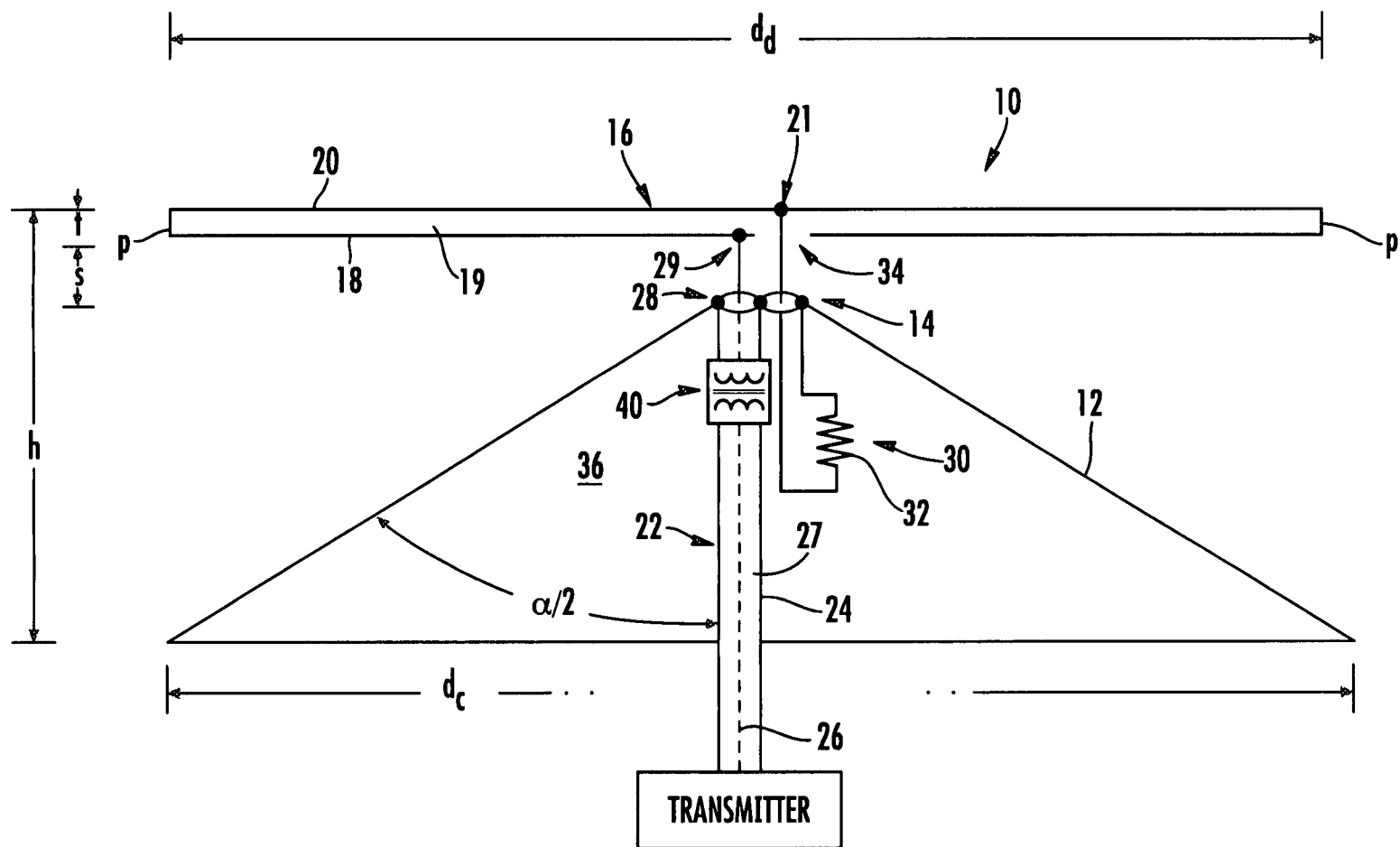
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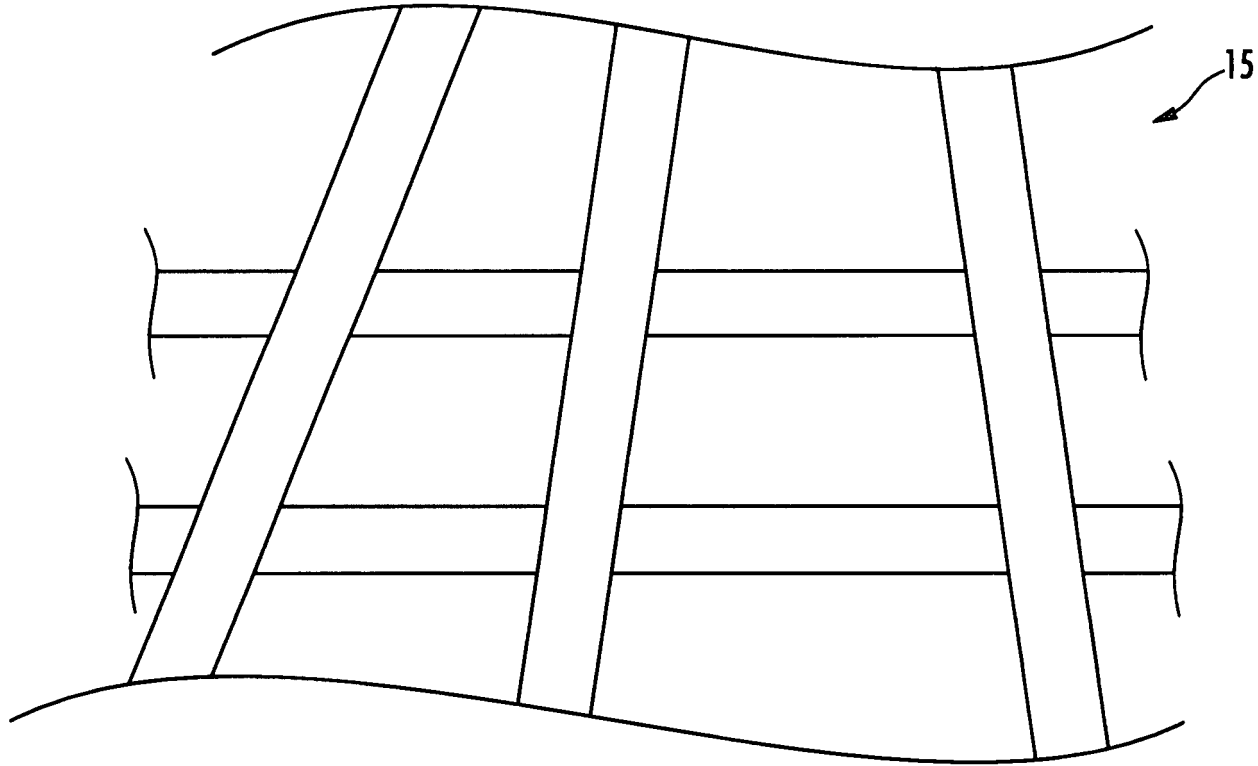


FIG. 2

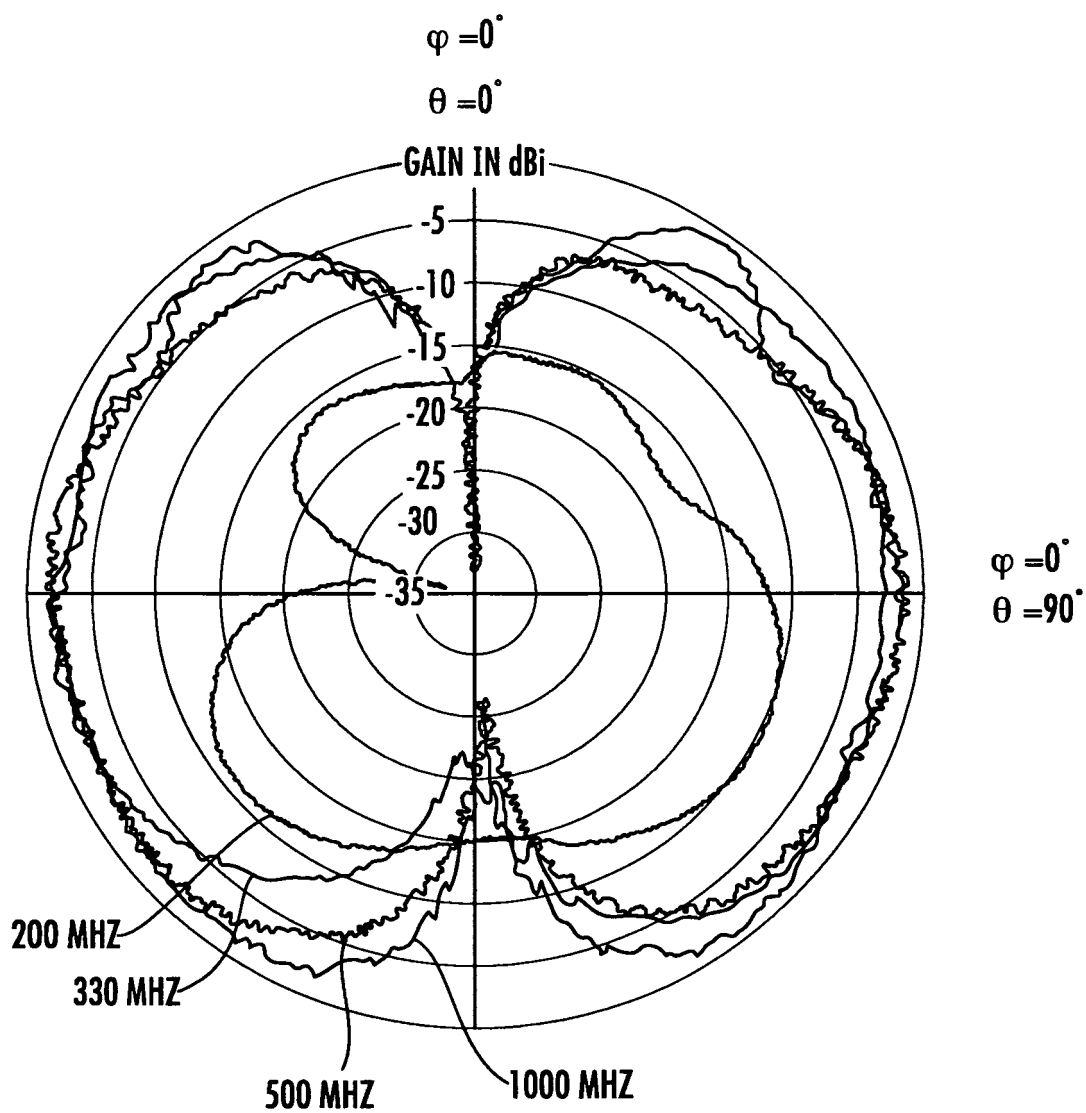


FIG. 3

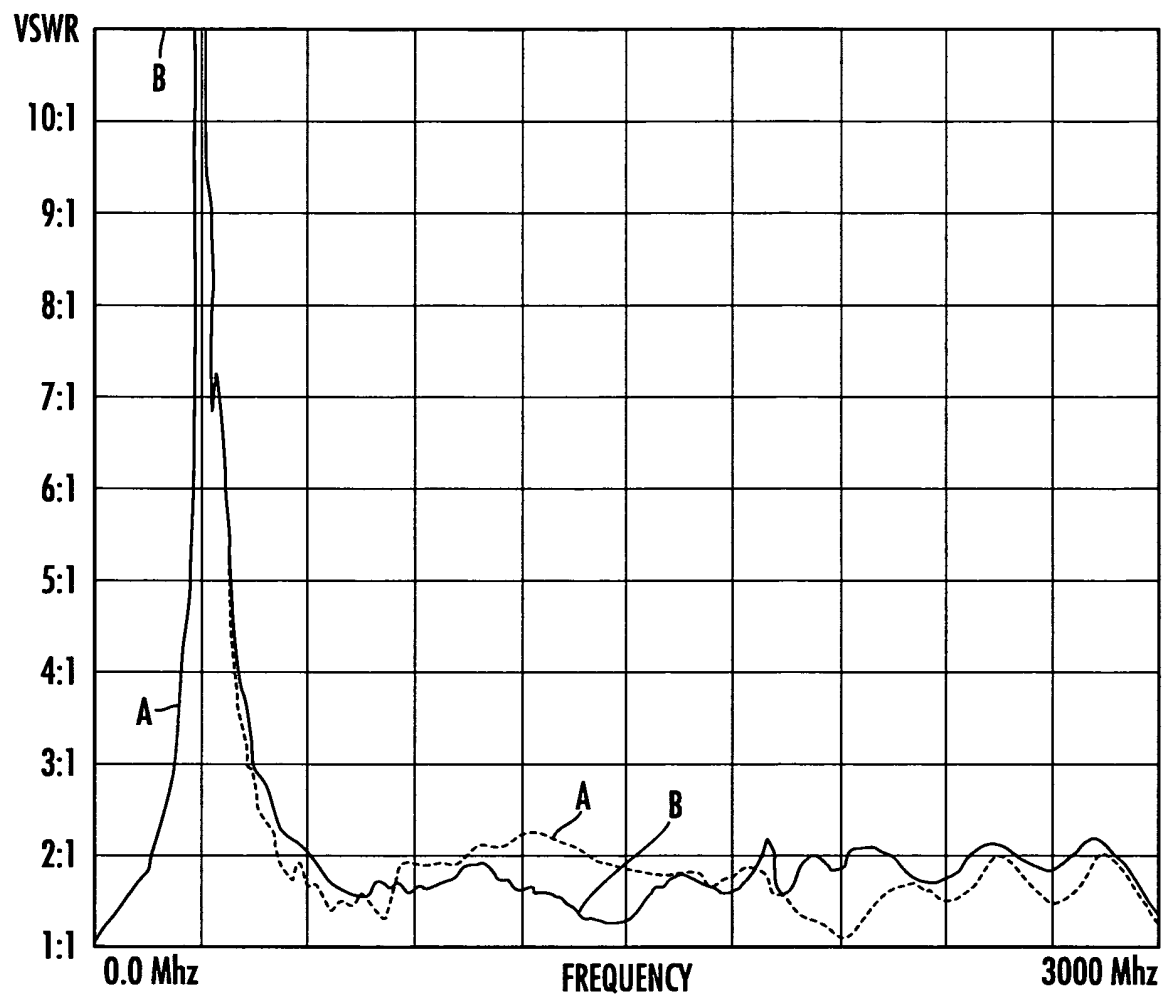
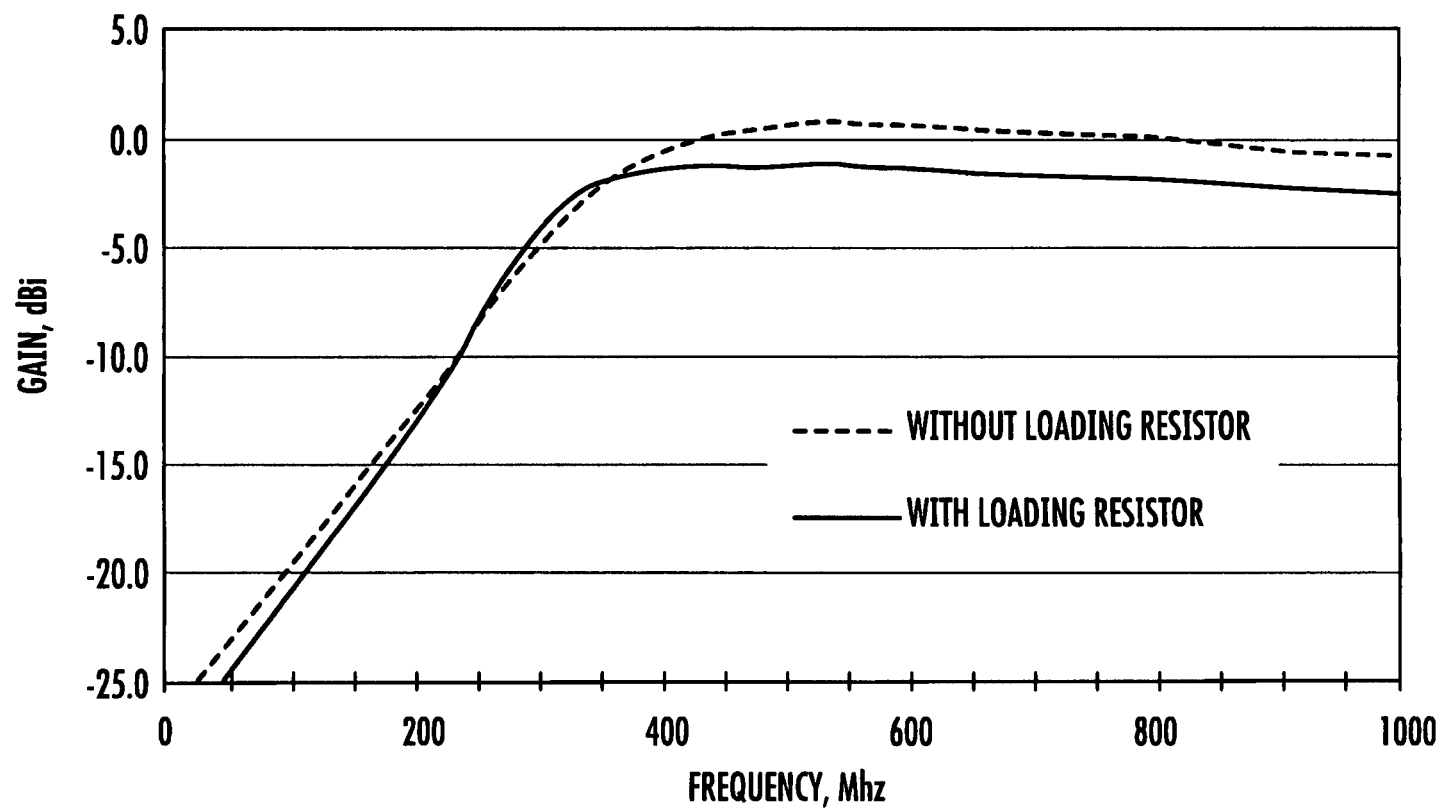


FIG. 4

**FIG. 5**

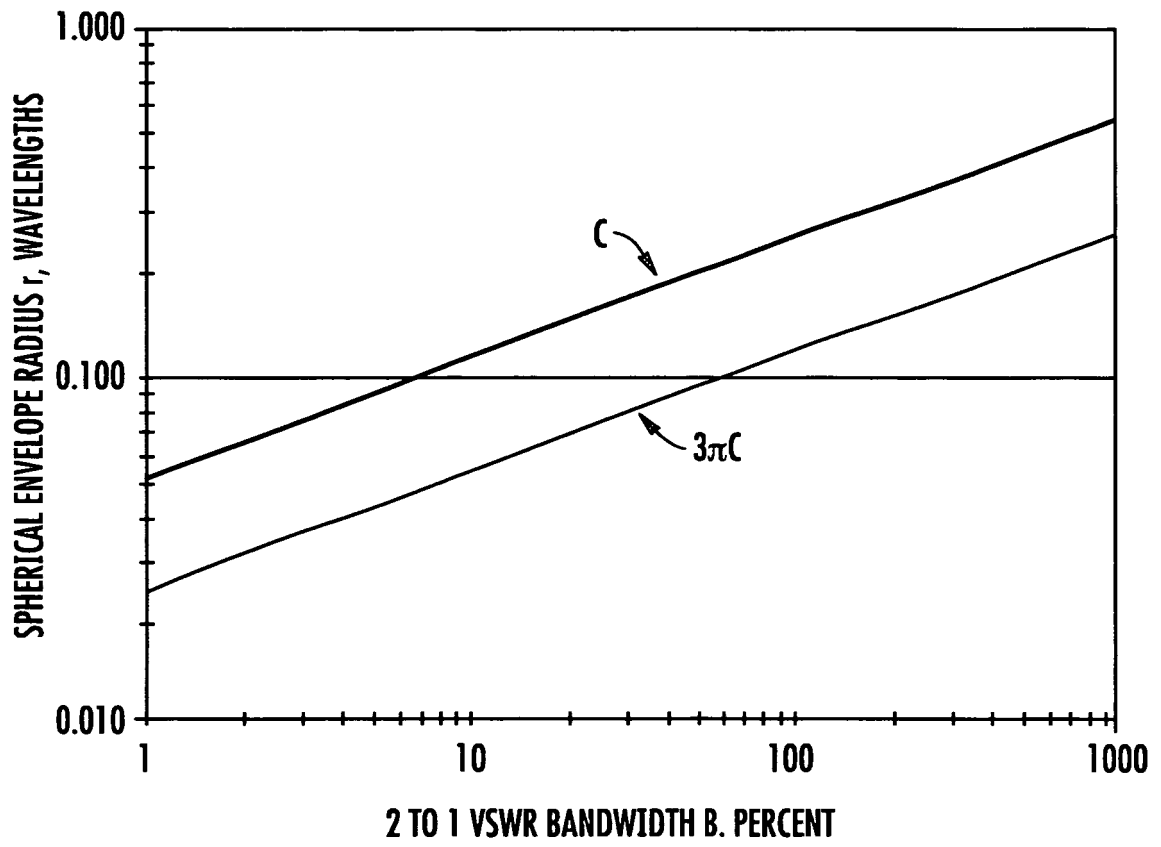


FIG. 6

REFERENCES CITED IN THE DESCRIPTION

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